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THE EMERGENCE OF THE CLINICAL RADIOLOGIST AND HIS PROBLEMS*

PRESIDENT'S ADDRESS

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SELDOM is one privileged to present to his colleagues the philosophy he has developed during twenty-five years of radiologic practice and to discuss the future of radiology. Many of the Presidential Addresses of my distinguished predecessors dealt with measures for establishing radiology as the clinical practice of medicine and pointed out that the best radiologists are necessarily well informed clinicians. Largely due to their efforts and far-sighted leadership and to other radiologists of similar vision, our specialty is now acknowledged as the clinical practice of medicine. This was a singular achievement since this recognition had to be won first from our medical confreres and has only recently been confirmed in a court of law where it was decided that we were not hospital employees.

Radiology has reached the position where this principle is being established in the minds of the public who is starting to distinguish us from those who render technical medical service. Not even our neighbors, our fellow churchgoers, our brother Rotarians and probably not even our banker fully understand what we are doing. This failure to know our work as they do that of the surgeon, obstetrician, pediatrician and internist is the result of a fundamental deficiency—the failure of the radiologist to meet and to know the patient—a failure which we are beginning to recognize and overcome with the emergence of the clinical radiologist. This has not been a failure of commission or omission, but a natural occurrence in the evolution of radiology.

In the beginning, the pioneer radiologists had to impress their colleagues that pertinent information could be obtained from an interpretation of the shadows on the films alone—that this new method was of diagnostic value. In time it achieved clinical acceptance through brilliant advances by our members and by others as they applied it to all areas of the human body. Simultaneously, scientists, physicists and manufacturers were making contributions in the improvement of equipment, in dosimetry and in radiologic techniques.

With these developments came an ever

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increasing demand for radiologic services. In meeting it, the small number of radiologists scarcely had time to do the necessary fluoroscopy, interpret the films and keep up with the therapy. This huge work load had to be carried on by only a few hundred radiologists and later by but a few thousand.

With time at such a premium, it is little wonder that radiology grew up without radiologists interviewing the patients and requesting the referring physician to give them the clinical data. This arrangement was not efficient and certainly was an inadequate means of gathering information about the patient. Very few radiologists, if any, were satisfied with this patient-physician relationship and many began devising ways of improving it.

From this effort emerged the clinical radiologist whose distinguishing feature is that he assumes the responsibility for getting his own information about the patient. He goes about this as any physician does—first, by interviewing the patient; second, by reviewing the hospital record; and third, by directly communicating with the referring physician when indicated. This applies to all patients who come to his office or to his department in the hospital. For most patients, it takes little more than an introduction and a few words to elicit their chief complaints. When this is done, the patient knows that he has been seen by a physician and that he is going to have a medical examination. The radiologist has used the professional approach in which all physicians are trained. The patient realizes that the radiologist is a physician and that he has been introduced to the specialty of radiology.

This contact gives the radiologist the advantage of knowing what the patient looks like and of obtaining first-hand information concerning his medical problems—information that can improve the quality of the consultation with the referring physician. It also eliminates the criticism by the medical profession that we "don't see patients." The recent Attitude Survey by the American College of Radiology points out that a chief reason why more interns do not choose to specialize in radiology is the lack of a sound patient-doctor relationship.

Most of us will agree that an interview with the patient is desirable and may ask how it can be done. The answer, of course, is more radiologists per one hundred of examinations. Fortunately, today there is a good supply of radiologists, and more are in training. In the departments in the hospitals the radiologists cannot see every patient, but their associates and residents can. It is being done in most of the major medical centers today. In my opinion, the growing number of clinical radiologists and their staffs are influencing our relationships with hospital administrations because the utilization of sufficient radiologists to give this type of radiologic service requires a larger financial budget for medical personnel. This helps to eliminate surplus funds that accrue in professionally understaffed departments. When such funds accumulate, they become a focal point of interest of hospital administrators and form the basis of many conflicts between radiologists and hospitals. The advantages accruing to the hospitals from clinical radiologists are that they increase the volume of work, enhance the medical stature of the hospital and provide the patient with better diagnostic and therapeutic radiology.

In his development, the clinical radiologist must obtain certification in the use of radioactive materials. Hospital administrators need a full time member of the medical staff who will be responsible for the handling and distribution of radioactive isotopes in accord with the policies determined by the Isotope Committee. To acquire this experience may mean another year of training and, if so, part of it could be devoted to supervoltage therapy. The value of supervoltage irradiation is now well established and the young radiologist must be competent to use it.

In the management of patients with advanced cancer, the clinical radiologist must

be well grounded in the use of hormones. He must be competent to prescribe not only drugs for the relief of pain, but also those for the control of tensions and emotions.

The role of the clinical radiologist was considerably enhanced with the introduction of new and safer contrast materials because with them came more difficult, complex and hazardous examinations for which he assumed greater responsibility. The radiologist was no longer a bystander while other specialists performed the examination. He now participated on an equal footing with his colleagues and shared equally in the success or failure of the examination. Actually, the complexity of many of the examinations requires a team of medical specialists. With changes in staff appointments and with the continuous rotation of interns and residents, the radiologist should be the permanent hub about whom the others revolve. This is especially true in the angiographic procedures, be they cardiac, cerebral, abdominal or peripheral, for he is the only member common to the different teams of specialists. In my experience, as soon as he demonstrates a superior knowledge about a diagnostic procedure such as pneumoencephalography, myelography or hysterosalpingography, the consulting physician will shift the responsibility and performance of the examination to him. Where a dozen examinations of a particular type are performed by one specialty, the radiologist will do another dozen with related specialties and several dozen with different individual specialists. Thus, from continuous application, the radiologist stands to gain a fund of knowledge and depth of experience that few physicians can hope to attain. With the rising importance of his position, the clinical radiologist will gradually assume more responsibility, not only in the performance of examinations, but also in evaluating the anticipated results as weighed against the radiation exposure.

Today a difficult task faces the clinical radiologist—that of minimizing ionizing radiation to the gonads. The arrival of the "Atomic Age" has emphasized the deleterious effects of radiations on the gonads. It was not until the hazard of "fallout radiation" from atomic weapons was recognized that serious consideration was given to the increment induced from the medical use of roentgen rays.

In discussing this problem, let us keep in mind that no single discovery in the history of medicine has succeeded in helping so many people with harm to so few as has been the incorporation of diagnostic radiology into the practice of medicine. With it came the elimination of guesswork for countless diagnoses, the avoidance of most exploratory operations, the advantage of being able to follow the ravages of infections, the opportunity of studying the progress of recovery from disease, and the ability to detect disease and tumors in the early stages. Without diagnostic radiology, medicine today would descend behind an "impenetrable curtain."

No one wants to do away with diagnostic radiology. The need is to see that it is used when really indicated; performed by trained physicians and the gonads shielded in the younger age groups. It is the unnecessary examination and those poorly performed by physicians and others who have received no radiologic training that are to be condemned. There are no legislative requirements or even self-imposed standards of minimal radiologic training in the medical profession to determine those who may be competent to use roentgen rays. The radiologist is the only physician with three additional years of formal training and who must pass examinations by the American Board of Radiology before he is certified to practice radiology.

For example, there is a small group of physicians in the various specialties who, after a few months or possibly a year of training, set up offices and proceed to do all types of diagnostic roentgenographic examinations. To ease the payments on the machine and the expenses incident to its

operation, they soon invite one, two or even half a dozen other physicians to use their equipment, although none of the others had any radiologic training. In most instances, radiation protection to personnel and occupants of neighboring offices afforded by monitoring and barriers is nonexistent. The setup is one for increasing income, rather than for increasing service to the patient and providing better diagnostic examinations. This situation can be obviated by eliminating short training periods in departments of radiology.

Another abuse that occurs too frequently is the purchase of roentgen-ray equipment by untrained physicians who are enticed by advertisements and salesmen extolling the earning power and the simplicity of the operation of machines that require only the "turn of a knob" to roentgenograph any part of the body. The manufacturers are not restricted as to whom or for what purpose they may sell their equipment. They are not yet restrained by legislative codes that enforce the construction of adequate radiation barriers in the walls and floors of rooms surrounding roentgen-ray machines. While most manufacturers and dealers conscientiously recommend or even insist on radiation barriers, there are still too many machines being installed without them. This is done because the added expense and construction problems for barriers would make the sale prohibitive—a situation which results in needless exposure to personnel and people in adjacent space.

One of the largest sources of unnecessary radiation to the gonads is the routine fluoroscopy of small children and particularly of infants by some physicians and pediatricians. In fluoroscoping an infant, it is difficult to avoid exposure to the gonads because of the small size of the patient and, consequently, they are hit by the direct beam. To appreciate the amount of radiation that can be given, one has only to remember that one minute of continuous fluoroscopy produces the same radiation dosage as 600 chest roentgenograms! All of us in the medical profession must avoid indiscriminate and careless use of the fluoroscope.

In this connection, the routine pelvimetric examinations of pregnant women should be reduced to only the most urgent indications as in this procedure not only are the maternal gonads irradiated, but the fetus also receives total body irradiation. There are other roentgenographic techniques that have to be re-evaluated on the basis of the importance of the information to be gained as compared to the radiation exposure.

Medical exposure to radiation can be further reduced by opposing health insurance plans that promote unnecessary roentgenologic examinations by encouraging untrained physicians to take roentgenograms equal in cost to the amount provided by the policy. I do not need to tell you that such plans exist which pay up to $25.00 per year for diagnostic roentgenologic examinations performed by any physician and that many policy holders receive $25.00 worth of radiation each year. This can be remedied by encouraging health insurance plans of the deductible type in which the patient must pay the first $25.00 in charges for roentgenologic studies.

The clinical radiologist can render medicine a distinct service by accepting the challenge to eradicate the unnecessary, the careless and the unscrupulous use of roentgenologic examinations and to bring them to light. They are as reprehensible as fee-splitting and can be eliminated by the same courageous action by the medical profession that weeded out that nefarious practice.

As radiologists we have done fairly well in shielding our patients, our personnel, our neighbors and ourselves from the somatic effects of radiation, but not as well as we should have done. There are still too many departments and offices without radiation monitoring devices, too many in which fluoroscopy is overdone, and too many in which the diagnostic machines are not calibrated for output.

We are far more conscious of our faults and are working to correct them, but we

must work harder and faster. For years we have kept down radiation exposure to our patients by adequately filtering the roentgen-ray beam by diaphragming the beam to the smallest dimension consistent with the part to be examined, by minimizing fluoroscopy and substituting roentgenography whenever possible, and by utilizing up-to-date equipment with built-in protective features. However, we must be more efficient and meticulous in doing this. We have been slow to develop radiation protective devices for sheltering the gonads in adults thirty years of age and under and especially in children and infants. These are being developed, but it takes time to perfect them for general usage.

The radiologists, the radiation physicists, and the radiobiologists working together through their national organizations have provided the leadership for making recommendations for minimizing radiation exposure for medical purposes. These groups have the experience, the training and are the best equipped to supply sound advice. Recommendations should not come from headline seekers, professional do-gooders or advertising self-styled consultants in radiation. They should continue to be an orderly dissemination emanating from authoritative organizations that have been working with these problems for years; such as the International Commission on Radiation Protection, The National Committee on Radiation Protection, the American College of Radiology, The Committee on Radiology of the National Research Council, The American Roentgen Ray Society, the Radiological Society of North America, and the American Radium Society. To this end the Commission on Units, Standards and Protection of the American College of Radiology is preparing a booklet on radiation problems for distribution to all members of the medical and allied professions. Similarly, the Committee on Radiology of the National Research Council, together with the American College of Radiology, is working on plans for a closed-circuit television program and on how to keep radiation exposure to a minimum. Organized radiology is not inactive. Neither are we defiant. We are meeting the problem with more efficient techniques and bringing to light abuses in the indications for and in the performance of roentgenologic examinations.

In concluding, we may say that in the Atomic Age the radiologists have assumed the responsibility of working more assiduously to minimize radiation exposure, that they will continue the leadership in distributing authoritative radiologic information, that the emergence of the clinical radiologist is a forward step, and that radiology has a solid future. At least these are my humble opinions. I should like to close with a quotation on opinions by the poet, Milton, who wrote, "When there is much desire to learn, there of necessity will be much argument, much writing; many opinions; for opinions in good men is but knowledge in the making."

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RADIATION HAZARDS AND WHAT IS BEING DONE ABOUT THEM

A SYMPOSIUM*

INTRODUCTION AND STATEMENT OF PROBLEM

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SO MUCH has been written and said recently about the dangers from radiation that in some quarters confusion has resulted. The effect on an appreciable number of individuals has been to frighten them to the point where they refuse even very desirable roentgenologic examinations. The really tremendous difference between the somatic damage to the exposed individual and the possible genetic damage to the race has not been made clear, so that people beyond the child-bearing age object to dental roentgenograms or to roentgen examinations of broken bones. They do not know what they are afraid of—they are just afraid.

The radiologist, who is quite well aware that he is working with a dangerous tool, is likely to be impatient with this attitude. It is traditional that the patient must have confidence in his physician—or get another physician. Unreasoning fears are hard to deal with, and the radiologist feels that he is too busy to spend hours explaining; he may believe that reassurance should be enough.

On the other hand, he may think, in view of all the recent discussions regarding somatic and genetic damage, maximum permissible doses in controlled and uncontrolled areas, and so on, that he himself would like some reassurance that he is doing the right thing, or some instruction as to what to do if his procedures need improvement. He would like to give intelligent answers to intelligent questions, and at present he cannot go to a book somewhere and find the facts set down in an unequivocal manner.

Furthermore, over and above the unreasoning fears of partially informed patients, the radiologist encounters a very real and growing interest on the part of his colleagues and among his non-medical associates, as to what this radiation hazard talk is all about. He is naturally expected to know; it is in his field. He is asked to explain it to medical groups, to hospital administrators, to various civic organizations. These different backgrounds may require somewhat different approaches to the material, but the basic facts are the same for everyone.

The present symposium has been arranged with the idea of summarizing for radiologists the present state of our knowledge with regard to radiation hazards both to the individual and to the race, and our plans to keep these at a minimum. Roentgen rays and radioactive isotopes are extremely valuable medical tools; their worth must never be lost sight of in any consideration of their harmful effects. Both in the individual case and for the whole population, the good must be weighed against the bad.

We now know a good deal about the effects of radiation on individuals exposed to various amounts of it. Dose levels have been established below which no effect is expected to be observed in the person irradiated, and it is possible to maintain radiation exposures below these levels for workers and for patients undergoing diagnostic procedures. Much less is known of possible

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The papers of Gioacchino Failla, Sc.D., Bentley Glass, Ph.D., John S. Laughlin, Ph.D., Lauriston S. Taylor, Ph.D., Carl B. Braestrup, B.S., P.E., Robert S. Stone, M.D., and Richard H. Chamberlain, M.D., which follow, are part of this symposium.

genetic hazards, but it is believed that there is no lower limit for the production of gene mutation. It is not possible for anyone to avoid all radiation; cosmic and earth radiations are inescapable. It, therefore, becomes a problem to determine what level greater than these can be considered as not affording a serious risk for the population as a whole. In this connection it must be constantly kept in mind that it is not the radiation received by any one individual that is important, but the *average to the entire part of the population between conception and the end of child-bearing*. In this matter, radiation received by older people is of no consequence whatever. And it may be very important for future generations that some individuals have their troubles correctly diagnosed and treated, even at the cost of considerable radiation to themselves. In the average this will be completely diluted out.

Each speaker in this symposium is a specialist in his own field. Each has had to do a great deal of selecting and condensing of his material in order to fit what he considers important into a brief presentation. It is obvious that the symposium cannot supply exhaustive information on all aspects of the problems of radiation hazards, but it should furnish basic data and point the way to a broad general understanding of the subject.

The first two talks will present the fundamental situations for the irradiated individual and for the population as a whole, pointing out the distinction between the somatic and genetic problems. The next two speakers will deal with exposures in current diagnostic procedures, and how these may be lessened. Then, since it has been found that long-continued exposure to low levels of radiation lessens the life span, the next speaker will look at this subject in relation to past and present safety practices. This will be followed by a realistic survey of the clinical safety problem. Finally, the high points of each presentation will be brought out in a general summary.

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THE SHORTENING OF LIFE BY CHRONIC WHOLE-BODY IRRADIATION*

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MOST of the information on life shortening by irradiation has been derived from experiments in which animals have been exposed acutely or intermittently to rather large doses, or have been irradiated chronically at fairly high dose rates. In all cases in which the daily dose has been less than 0.5 r, no statistically significant life shortening can be determined because of the small number of animals used. However, by making certain assumptions and using experimental data obtained at the higher exposure levels, mathematical relationships have been derived that permit the calculation of the life shortening to be expected in man from whole-body exposure at a given dose rate or with a given total dose. The figure most widely quoted is that 1 r shortens man's life by fifteen days,† according to calculations made by Hardin B. Jones.[4]

Dublin and Spiegelman[3] in their study of the mortality of medical specialists during the period 1938–1942 found that the mortality rate (from all causes) for radiologists was lower than that for all physicians but somewhat higher than that for all specialists combined. The mortality rate from cancer (especially leukemia) for radiologists was distinctly higher than for nonspecialists. From this it may be surmised that the life expectancy for radiologists may be slightly lower than for all medical specialists combined, principally because of the higher cancer incidence, but nevertheless it is higher than that of all physicians taken together. A recent survey made by Shields Warren[7] shows that the mean age at death for radiologists who died between 1930 and 1954 was 60.5 years as compared to 65.7 years for other physicians having no known contact with radiation. The accumulated doses received by these radiologists in the exercise of their profession are estimated to vary from rather low values to about 1,000 r. However, Lewis[5] has pointed out that if account is taken of the age distributions of these radiologists and the physicians with whom they were compared, a difference of at least six years would be expected on this basis alone. That is, radiologists may have a slightly longer lifespan than physicians as a whole, as indicated in Dublin and Spiegelman's study. Assuming that the average radiologist of that period received a whole-body dose of 500 r in thirty-five years (from age twenty-five to sixty)—which cannot be too far from the actual value—the life shortening should have been 20.5 years on the basis of fifteen days per roentgen.

Insofar as radiologists exposed at present permissible levels are concerned, the shortening of life may well be assumed to be negligible. However, when the accumulated dose is much larger, there must be a shortening of life and it would be well to be able to predict its magnitude. To indicate the method by which this may be done, use will be made of the experimental data of Lorenz *et al.*[6] on chronic irradiation of LAF_1 mice until death. The treatment of the data will be in terms of the Gompertz function used extensively by Jones.[4] This in fact has been done by Berlin and Dimaggio[1] and some of their numerical values will be used also.

Study of the set of curves published by these authors shows that they are not in the proper relative positions. Assuming that the Gompertz function is applicable (which

† The extreme limits set by Jones are one to thirty days per r.

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is reasonable), this must be attributed to the paucity of experimental data. The following procedure was used to try to overcome this difficulty. In order to plot the Gompertz curves for the different daily doses it is necessary to know the initial mortality rate, r_0, for the group of animals used and m, the slope of the straight line on a semilogarithmic plot. These quantities are usually derived from the experimentally determined mortality curves. Since for each daily dose only about 50 animals were used, high accuracy cannot be expected. However, if it is assumed *a priori* that the Gompertz function is applicable, the following mathematic relation may be used to calculate the slope m:

$$S_{1/2}=\frac{1}{m}\ln\left(1+0.693\frac{m}{r_0}\right)$$

where

$S_{1/2}$ = 50 per cent survival time
m = the slope
r_0 = initial mortality rate.

The values of $S_{1/2}$ experimentally determined are given in Table I. The value of r_0 was taken from Berlin and Dimaggio's publication[1] as the average of the values given by them for the irradiated groups; that is, $r_0 = 1.31 \times 10^{-4}$ days^{-1}.

TABLE I

SURVIVAL IN LAF_1 MICE EXPOSED DAILY TO GAMMA RADIATION

Daily Dose, r	$S_{1/2}$*, Days
0	703 ± 23
0.11	761 ± 26
1.1	684 ± 20
2.2	630 ± 20
4.4	591 ± 16
8.8	488 ± 11

* The 50 per cent survival time; that is, the time after beginning of exposure when one half of animals had died.

To facilitate the calculation, a curve of $S_{1/2}$ versus m was plotted from the above equation, assuming different values of m. Then the m's corresponding to the experimentally determined $S_{1/2}$'s were read from this curve. Since the slopes of the Gompertz curves should be linearly related to the daily doses, the values of m were plotted against daily doses and the best fitting straight line was drawn by inspection. From this, new values of m were obtained and from these m's new values of $S_{1/2}$ were read off the curve of the equation given above. This procedure served to average out errors and gave internally consistent values of $S_{1/2}$ and m for the different daily doses. The final values are given in Table II.

TABLE II

Daily Dose r	$m \times 10^5$ Days^{-1}	$S_{1/2}$ Days	$S_{1/2}$ Experimental	Ratio $S_{1/2}/S_{1/2}$ Experimental
0	4.45	720	703	1.02
0.11	4.48	716	761	0.94
1.1	4.83	678	684	0.99
2.2	5.22	643	630	1.02
4.4	5.98	583	591	0.99
8.8	7.51	494	488	1.01

The experimental values and the ratios are listed in the table for ready comparison to show that the changes brought about by the process of repeated adjustments are small. It might be mentioned in this connection that the survival curve for the controls in the experiment of Lorenz *et al.*[5] is definitely out of line. For this reason the value of r_0 for the controls given by Berlin and Dimaggio[1] was not used for the present purpose. The Gompertz curves for different daily doses are shown in Figure 1. (The curve for 0.11 r/day is not included because it is very close to the one for the controls.)

It will be seen that each straight line represents the increase in mortality rate (fraction of the number of individuals of a certain age dying per day) as the animals get older. For the controls this represents the spontaneous aging rate. Exposure to radiation at a given dose rate (daily dose) increases the slope of the line and, therefore, may be said to accelerate the aging

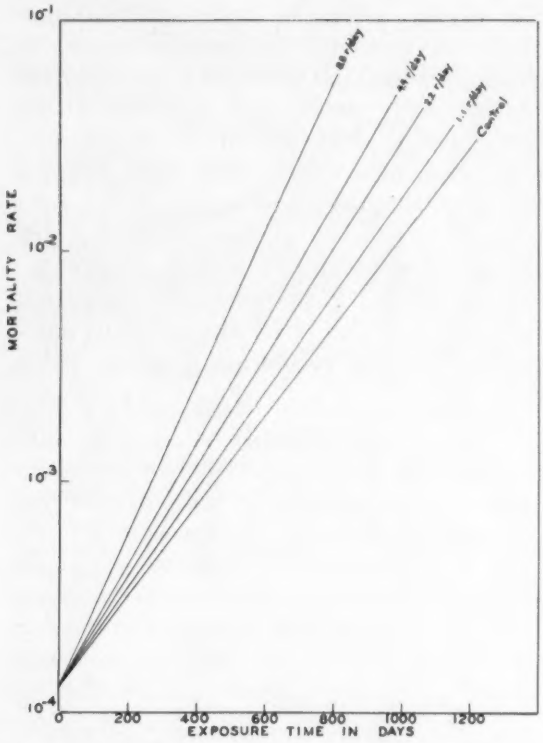

FIG. 1. Gompertz curves for mice. Mortality rate = fraction of mice alive at a given age dying per day. Exposure time = age of mice − age at start of experiment (about seventy days).

process. If these curves represent the true situation, spontaneous aging and aging brought about by chronic exposure to radiation may be considered to be additive. It should then be possible to assign a fictitious dose rate of radiation to the spontaneous aging curve (controls). This may be done in the following manner. The equation for each curve is

$$r = r_0 e^{mt}$$

where

r_0 = initial mortality rate
e = base of natural logarithms
m = slope of straight line
r = mortality rate at time t.

If we assign a fictitious dose rate of s "r"/day to the control curve, the equation becomes

$$r = r_0 e^{kst}$$

where

k = constant.

Since application of the Gompertz function to the mortality of animals irradiated at constant dose rate requires that the slopes vary linearly with dose rate, and this was indeed the way in which the relative values of the slopes were derived from the experimental data, the general equation for all the curves is

$$r = r_0 e^{k(s+\gamma)t}$$

where

γ = dose rate of applied radiation
s = fictitious dose rate for spontaneous aging.

This enables us to calculate s for the mice of Lorenz *et al.*'s experiment. From the data in Table II

$$k = 3.48 \times 10^{-4} \text{ in units of } r^{-1}$$

$$s = 12.8 \text{ "}r\text{"/day.}$$

This procedure may be justified in the following manner. In Table III, Column 2, are given the exposure times for different daily doses (Column 1) for which the mortality rate is 0.01, as read from Figure 1. The actual accumulated doses for these exposure times are given in Column 3. It will be seen that the accumulated dose for 8.8 r/day is much higher (4.27 times) than for 1.1 r/day. This means that radiation delivered at the rate of 1.1 r/day is about 4 times more effective than radiation delivered at the rate of 8.8 r/day in changing the mortality rate of the mice from the initial value to 0.01; that is, in aging the animals. This is the reverse of what one would expect. However, if to the actual daily dose γ is added a fictitious daily dose s of 12.8 "r"/day (Column 4) the total accumulated dose (Column 5) is the same for all daily doses. This, of course, is a mathematical trick, but it provides a simple way of taking into account spontaneous aging.

As pointed out by Jones,[4] the effect of exposure to radiation at a constant daily

Table III

FOR MORTALITY RATE $r=0.01$ (LORENZ *et al.*'S MICE)

1	2	3	4	5
Daily Dose γ in r	Exposure Time in Days	Accumulated Dose in r	$s+\gamma$	Accumulated Dose Fictitious and Actual "r"
0	976	0	12.8	12,500
1.1	898	986	13.9	12,500
2.2	832	1,828	15.0	12,500
4.4	726	3,195	17.2	12,500
8.8	578	4,215	21.6	12,500

dose may be thought of as an increase in physiologic age as compared to chronologic age. Thus, from Figure 1, after mice have been irradiated at 8.8 r/day for 420 days, the survivors have the physiologic age ($r=3\times10^{-3}$) of the controls at 710 days after the experiment was started. In other words, the irradiated mice have been aged by $710-420=290$ days by an accumulated dose of $8.8\times420=3{,}700$ r. Since in Figure 1 the total accumulated dose (fictitious + actual) is the same for any given value of the mortality rate r, the increase in physiologic age brought about by a given dose of radiation chronically administered may be determined simply by dividing the dose by 12.8. Thus, in the above example the accumulated dose was 3,700 r. Taking this as the fictitious dose accumulated by the controls at the rate of 12.8 "r"/day, we find that it would take $3{,}700/12.8=289$ days to do so, which is the difference between chronologic age and physiologic age found above. The difference is the same for the same accumulated dose, irrespective of the daily dose at which it is delivered, within the daily dose limits shown in Figure 1. Thus, with a daily dose of 4.4 r/day, it would take 840 days to deliver 3,700 r. At this time the mortality rate (for 4.4 r/day) would be 2×10^{-2} and the corresponding time for the controls would be 1,130 days. The difference is again $1{,}130-840=290$ days. This may be shown analytically as follows: For a given mortality rate r

$$(s+\gamma)t=st_c=\text{constant}$$

where

t = exposure time
t_c = time for which mortality rate of controls is r

and the other symbols are the same as before.

This holds for any combination of γ and t encompassed by the data of Figure 1. (The main point to bear in mind is that the highest dose rate used in the experiment was 8.8 r/day and it is not known how much higher it could be and still conform with the relationships derived earlier.) Then the difference between chronologic age and physiologic age is

$$t_c-t=\frac{\gamma t}{s}=\frac{D_{acc.}}{s}$$

where $D_{acc.}$ = accumulated dose (at any dose rate not greater than 8.8 r/day).

It is well known that the difference between chronologic age and physiologic age is somewhat larger than the life shortening. However, the former has the great advantage that to determine it, only the accumulated dose need be known—once the value of s has been determined. Therefore, it may well be used to determine the approximate life shortening. (It will be seen later that in the case of man a better procedure is available).

From the foregoing it is evident that for most practical purposes the extrapolation from mouse to man requires only a Gompertz curve for normal aging and the determination of the fictitious dose rate s, applicable to the chronic *whole-body* irradiation of man. Considerable importance should be attached to the italicized words. In the experiment of Lorenz *et al.*[6] the distribution of radiation was nearly uniform throughout the body, because of the small size of the animal and the high penetrating power of the radiation (radium gamma rays). Therefore, all organs received nearly the same dose and the life shorten-

ing was due to the summation of the effects in all organs. In man the distribution of radiation may be quite non-uniform, in which case the effect of a dose, as usually measured, would be expected to be less than when the distribution is more nearly uniform.

Curve *A* in Figure 2 is a representative Gompertz curve for man. It is a straight line only after age thirty-two but for the present purpose it has been extended to age twenty. The dotted portion of the curve represents the true mortality rate according to age, from birth to age thirty-two. The "doubling time," that is, the time required to double the mortality rate in the straight line portion of the curve is 8.5 years; hence, the slope is

$$m=\frac{0.693}{8.5}=8.15\times10^{-2}\ \text{years}^{-1}$$

$$=2.23\times10^{-4}\ \text{days}^{-1}.$$

The slope for the control mice was found to be 4.45×10^{-3} days^{-1}, which is 20 times greater than that for man. Therefore, these mice age 20 times more rapidly than man, per unit of time (per day). If the unit of time in Figure 1 is increased by a factor of 20 (in which case 200 days on the exposure time scale would correspond to 4,000 days, etc.) the control curve would have the same slope as the Gompertz curve for the spontaneous aging of man. Or, in Figure 2 Curve *A* can be made to represent the curve for the control mice by changing the age scale by a factor of 20, so that twenty years would represent one year of the life of the mice after the beginning of the experiment; thirty years for man = 1.5 years for mouse, etc. This applies, of course, to the straight line portion of the curves. If we change the time scale for age, we should change it in the whole system in the same proportion. Whence the fictitious dose rate corresponding to normal aging in man should be 12.8 "r" *per twenty days* or 0.64 "r"/day. Similarly, the aging effect of 1.1 r/day on mice would correspond to the aging effect of 1.1/20 = 0.55 r/day on man,

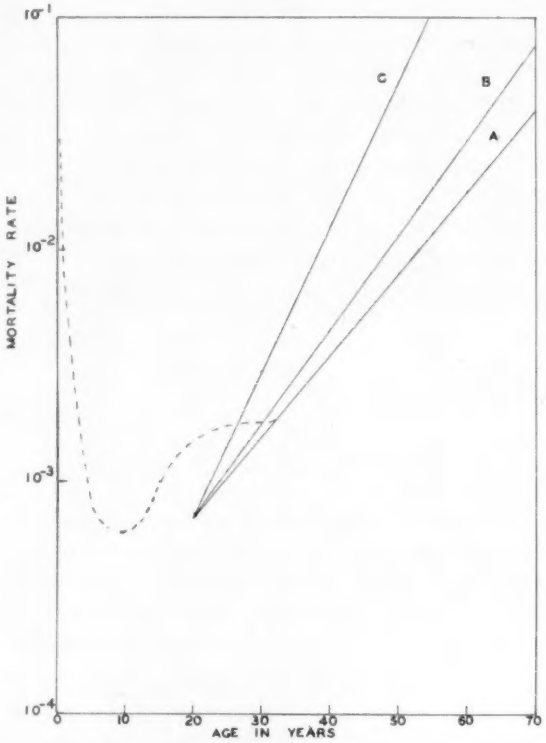

FIG. 2. Gompertz curves for man. Mortality rate = fraction of individuals of a given age dying per year. Curve *A* represents spontaneous aging. If fictitious dose rate for A = 0.64 "r"/day, Curve *B* corresponds to 0.1 r/day, and Curve *C* corresponds to 0.5 r/day.

etc. On this basis, Curve *B*, Figure 2 represents 0.1 r/day and Curve *C* represents 0.5 r/day.

Analytically, the problem may be treated as follows: First it should be noted that the Gompertz curve for man may be obtained from data compiled by the National Office of Vital Statistics and represents the true situation, since millions of individuals are involved. The one for mice is essentially an assumed curve, which may be in error by a considerable amount. Therefore, the slope is not known accurately. Assuming that it is correct, we have for the same initial mortality rate r_0 and the same mortality rate r at the same time t, in the Gompertz straight lines

$$r=r_0e^{m_ct}=r_0e^{Mt}$$

where

m_c = slope of straight line for control mice (Fig. 1)
M = slope of straight line for man (Fig. 2, *A*)

and

t = time in days.

Since the difference in the slopes was found above to be 20-fold

$$M = \frac{m_c}{20}.$$

Now, it was found that for the control mice

$$m_c = 12.8k$$

therefore,

$$M = \frac{12.8k}{20} = 0.64k.$$

Hence, by taking 0.64 "r"/day as the fictitious dose rate corresponding to spontaneous aging in man, we have assumed that k is the same for mouse and man. All we know for sure is the value of M (for man). If the analysis of the mouse data of Lorenz *et al.*[6] is reasonably correct, we also know m_c and k for mice. On the same basis there should be a k and a fictitious dose rate s for man. Denoting these quantities for man by k_M and s_M we have

$$s_M k_M = \frac{1}{20} sk = 4.45 \times 10^{-3}$$

where s and k represent the values for mice already found. It is evident that the values of s_M and k_M may vary widely so long as their product equals 4.45×10^{-3}. Therefore, in order to determine the fictitious dose rate s_M for man it is necessary to know whether $k_M = k$ or, if it does not, how it differs from k. A preliminary analysis of experiments on rats similar to Lorenz *et al.*'s experiments on mice conducted by Dowdy, Boche and Bishop and reported by Boche[2] indicates that k is very nearly the same for rats. This, however, may be an accidental coincidence and in any case not much weight can be given to it in the extrapolation to man, since the life spans of rats and mice are nearly the same. It may be possible to get some guidance by considering the physiologic implications.

In our analysis we are really postulating that there is some agent (of unknown nature) that is responsible for spontaneous aging in mouse and man. The agent need not be the same in both cases, but its potency is expressible in some unit "r," equivalent to one roentgen. Since $s \times t$ has the unit of dose ("r"/day × days), assuming a constant k for man and mouse implies that a certain dose of this hypothetical agent produces the same change in mortality rate in both mouse and man. On this basis the agent is equally effective in producing aging in both man and mouse. Since the time required to do this in the case of man is 20 times longer than in the mouse case, the fictitious dose rate for man must be 1/20 of that for mouse. On the other hand, we may get the same result by assuming that the spontaneous aging agent has the same dose rate (12.8 "r"/day) for both man and mouse, but it is 20 times less effective in producing aging in man than in the mouse. This would imply that the biologic system of man is 20 times more stable, vis-à-vis the hypothetical aging agent, than that of the mouse. At the moment no choice can be made between the two alternatives. (As pointed out earlier, these are not the only two possible alternatives). Since the comparison between man and mouse is usually made on the basis of life span; that is, by changing the age scale in the ratios of the life spans, Curves *B* and *C* of Figure 2 have been determined on a similar basis but using the factor of 20, which applies to the respective Gompertz straight lines.* Therefore, in Figure 2 the fictitious dose rate for spontaneous aging in man (Curve *A*) is 0.64 "r"/day. The corresponding dose rates for Curves *B* and *C* are 0.1 r/day and 0.5

* The ratios of life spans are usually taken as 30 to 36. Our ratio of 20 is considerably smaller than this, but comes out directly from the slopes of the two straight lines. As pointed out earlier, the slope of the line for the control mice is not known accurately. On the other hand, it should not be assumed that the two slopes should be in the ratio of the life spans, since the variation of mortality rate with time is very different for man and mouse before middle age.

r/day, respectively. If it is assumed that the fictitious dose rate for man is the same as that for mouse; Curve *A* corresponds to a dose rate of 12.8 "r"/day and Curves *B* and *C* to 2 r/day and 10 r/day respectively.

We may now estimate the life shortening in man to be expected from chronic whole-body exposure to roentgen rays of high penetrating power. The simple method worked out for mice will be used and, therefore, only the spontaneous aging Curve *A* in Figure 2 and the fictitious dose rate applicable to that curve are needed. The curve was extended down to age twenty in order to consider cases of occupational exposure that may begin at that age.* If exposure is at an average rate of 0.1 r/day for 40 years, the accumulated dose at age 60 will be 1,460 r. Taking the fictitious dose rate for man as 0.64 "r"/day or 234 "r"/year, the increase in physiologic age will be 1,460 /234=6.25 years. Therefore, at age sixty the individual would have the physiologic age of a nonexposed individual 66.25 years old. The life expectancy of United States white males (as of 1950) is sixteen years at age sixty and twelve at age 66.25. Therefore, the life shortening is four years or

$$\frac{4\times 365}{1{,}460} = 1 \text{ day per } r.$$

Obviously, if the fictitious dose rate for man is 12.8 "r"/day, the life shortening will be approximately 1/20 of a day per r. Therefore, life shortening determined on the basis of a fictitious dose rate of 0.64 "r" /day may be considered to give a reasonable upper limit. There are, of course, some variations in the life shortening per r when the above calculation is made for other ages, because the life expectancy is not a linear function of age, but the maximum is approximately 1.5 days per r. Considering the inherent uncertainties involved, an average value of 1 day per r is a close enough estimate.

These calculations have been made for a daily dose of 0.1 r because Curve *B* of Figure 2 is for 0.1 r/day on the basis of 0.64 "r"/day for Curve *A*, and the age difference can be read directly from the curves. As pointed out earlier in the case of the mice, so long as the exposure is chronic and the dose rate not too high, the dose accumulated up to the age of interest is all that is needed to determine the approximate life shortening. Thus, in the case of the radiologists in Shields Warren's survey,[7] if we take 500 r for the average dose accumulated up to age sixty, the age difference is

$$\frac{500}{0.64\times 365} = 2.14 \text{ years.}$$

The life expectancy is sixteen years at age sixty and 14.5 at age 62.14. Therefore, the life shortening to be expected is 1.5 years (which corresponds to 1.1 day per r). The present permissible limit for accumulated dose for those occupationally exposed is 210 r at age sixty. The life shortening to be expected on the basis of our assumption is less than two-thirds of a year.

* In this country the minimum legal age for work with radiation is actually 18.

SUMMARY

The data of the experiment of Lorenz *et al.*[6] on chronic irradiation of mice with radium gamma rays have been analyzed in terms of the Gompertz function in such a way that the resulting curves are internally consistent. The straight line for the controls (on a semilog plot) represents the increase in mortality rate with age of the animals. It is customarily assumed that, at least beyond a certain age, the increase is due to the aging process, whatever it may be. The slope of the straight lines for the chronically irradiated mice is greater than for the controls. Therefore, chronic whole body irradiation causes an acceleration of aging in these mice. Irrespective of the mechanism by which radiation causes aging, the effect is additive to the spontaneous one. From the relative positions of the straight lines (Fig. 1) it is then simple to calculate a fictitious dose rate of radiation that would produce the same aging as occurs spontaneously. This turns out to be 12.8 "r" per day. Adding this fictitious

dose rate to the actual gamma-ray dose rates used in the experiment makes the total accumulated dose at the time when the groups of mice have equal mortality rates the same, irrespective of the dose rate (within the limits of the experiment, 0–8.8 r per day). This is as it should be if the effects of the spontaneous aging process and aging by irradiation are additive.

For man the Gompertz curve is known accurately, but varies from country to country and to some extent with the year when the statistical data were compiled. The one given in Figure 2 applies to the white population of the United States. It is not known how this population would respond to chronic irradiation and, therefore, it is impossible to determine directly the fictitious dose rate that would produce aging equivalent to spontaneous aging. However, a value may be obtained by comparing the Gompertz straight lines for the control and chronically irradiated mice (Fig. 1) with the straight line portion of the Gompertz curve for man (Fig. 2 *A*). It is found that the slope of the straight line for the nonirradiated mice is 20 times greater than the slope of the straight line for man, when the same time scale is used. This means that the mice used in the experiment of Lorenz *et al.* age 20 times faster than man. It is reasonable to assume then that the fictitious dose rate for man is 1/20 of that for these mice. Obviously, if the life span of mouse is shorter than that of man, either the aging agent (whatever it may be) is more powerful in mouse than in man, or the biologic system of man is more stable than that of mouse. Be that as it may, the time rate of aging differs by a factor of 20. If we use this factor to determine the fictitious dose rate for man we find that it is 0.64 "r" per day. On the same basis the aging produced in mice by 1 r per day should be produced in man by 1 r in twenty days; that is, by 0.05 r per day. This makes possible the estimation of the life shortening in man to be expected from chronic exposure at any given dose rate (not in excess of 8.8/20=0.44 r per day, 8.8 r per day being the highest dose rate used by Lorenz *et al.*). A simple method for doing this is described in the text.

The most widely quoted estimate of the life shortening to be exepcted in man from exposure to radiation is one made by Hardin B. Jones,[4] which is fifteen days per roentgen. The value derived by us is approximately one day per roentgen of accumulated dose for chronic exposure at a dose rate not in excess of 0.5 r per day. The National Committee on Radiation Protection has recommended a maximum permissible accumulated dose of 50 r in ten years for individuals occupationally exposed to roentgen or gamma rays. This amounts to 210 r in forty-two years (age eighteen to sixty). According to our method of estimation, the life shortening attributable to this accumulated dose is about two-thirds of a year. On the same basis the life shortening to be expected in radiologists who in the past (when the dangers of exposure to radiation were not well known) may have accumulated whole-body doses of 500 r is 1.5 years.

It should be noted that the method of extrapolation from animal to man developed by us has only one new feature—the assignment of a fictitious dose rate to spontaneous aging. This is really a necessary consequence of the application of the Gompertz function to the mortality of chronically irradiated animals. Therefore, if this is justified, the extrapolation according to our method is correct *in principle*. However, owing to the small numbers of animals used in chronic exposure experiments, the derived numerical values for man may have a considerable error, but this would not be so large as to make the life shortening in man equal to anything like fifteen days per roentgen. It is well to point out explicitly that the present discussion applies only to chronic exposure at low dose rates—not to the effect of a large dose received in a short time.

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THE GENETIC BASIS FOR THE LIMITATION OF RADIATION EXPOSURE*

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TODAY one must begin to think of mutations of the hereditary material in terms of its chemical nature and of the possible changes in it which would be capable of modifying the genetic information transmitted by it from one generation to the next. Chromosomes, the well-known microscopically visible carriers of the genes, are composed of deoxyribose nucleic acid (DNA), some ribose nucleic acid (RNA), considerable basic protein (histone), and a little protein of a higher molecular weight. The evidence now available clearly indicates that the genetic information is coded primarily in the DNA. If so, it can only reside in the sequences of the purine and pyrimidine bases (adenine, guanine, cytosine, and thymine) along the length of the polynucleotide chains that comprise the DNA molecule. Mutations, then, are alterations in this material which, when chromosomes reproduce themselves, are themselves replicated and thus transmitted through both mitotic and meiotic cell divisions.

The hereditary material is of course present in the nuclei of all cells, not of reproductive cells alone. Any damage done to it is transmitted through mitosis to all the somatic descendant cells. Many, if not all, genes are concerned with the presence and specificity of particular enzymes, each of which governs some particular step in the metabolic pattern. Unless, in certain tissues, the blocked steps have become unimportant, the damaged genes must result in damaged cells; but most metabolic steps, as the biochemists find, are important in most, if not all, differentiated tissues. Extremely few steps can be altered with impunity. Most of them, in fact, are everywhere essential. It is little wonder, therefore, that when a mutation impairs the specificity of an enzyme and thereby blocks a particular metabolic step more or less completely, the usual outcome is fatal unless the cell has some alternative way of supplying its needs. In a multicellular animal the incapacitated cell may live on at the expense of its neighbors. Or it may die, and this is not so serious if there are limitless numbers of uninjured cells to take its place. Only if the damaged cell is irreplaceable, or if it should be stimulated to abnormal activity and multiplication at the expense of other cells (leukemia, cancer), is the fate of the entire organism imperiled. But if very great numbers of somatic cells are damaged genetically, the effect may be very severe, even though not uniform in character. Thus most mutations may be expected, as Crow[1] has recently said, not to result in conspicuous abnormalities but to be manifested "simply as an increase in the types of abnormality, disease, and death that are already occurring."

What is true of the nature of genetic damage in somatic cells is more fully revealed in the consequences of damage to the reproductive cells. In this case the hereditary defect will be present in every cell of the offspring to whom it is transmitted via egg or sperm, and no tissue can escape the consequences of the defect. The sole safeguard, in each such case, is the general probability that the set of genes inherited from the other parent will not carry any of the same hereditary defective genes. Morton, Crow, and Muller[2] have recently calculated, for example, that the average number of lethal genes (or of more numerous but less harmful genes adding up to the same degree of harm) carried by each of us amounts to four. It is consequently only because of our double inheritance, coming

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from ancestral lines that rarely carry the same harmful genes, that we survive at all.

Ionizing radiations produce mutations. Visibly, we note, as a result, broken and rearranged chromosomes. These chromosomal mutations are commonly so harmful they are eliminated almost at once through the early death of their carriers, and they are produced in negligible frequencies except at high doses of acute radiation. Furthermore, in the germ line they are almost wholly limited to occurrence in spermatocytes, spermatids, and mature spermatozoa, which are in large measure destroyed by the high doses of acute radiation that produce the well-known temporary male sterility following radiation of the testes. More significant to the population, therefore, are those less harmful, usually mainly recessive mutations which affect individual genes—the submicroscopic lesions that presumably consist of alterations in the sequence of purine and pyrimidine bases, through inversions of segments, insertions, deletions, and substitutions.

Our present evidence indicates that the frequency of these point mutations always increases linearly with the radiation dose (Fig. 1). In Drosophila studies this holds over the range from 25 r up to 6,000 r. In some plants, the linear range has been extended down to about 5 r. In mice, the linearity in relation to dose holds over the range from 300 r to 600 r, and there is no sign that it does not hold at lower doses. This linear proportionality to dose, over and above the spontaneous frequency of mutation, implies that (a) as long as dosage is measured in terms of roentgens, that is, in terms of the ionization produced by the radiation, absorbed quanta do not interact to produce effects, but are individually ef-

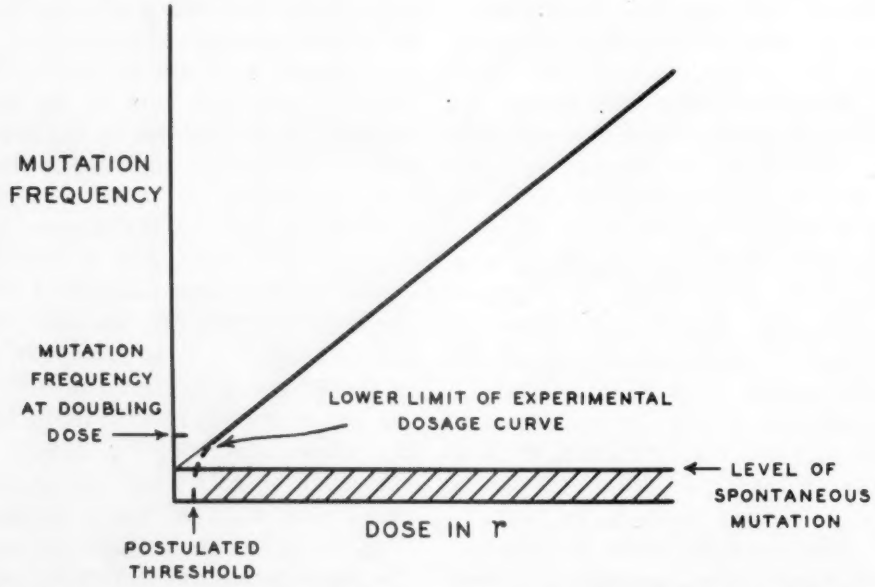

Fig. 1. Diagram to represent the relationship between mutation frequency and man-made dose of ionizing radiation. Note that the mutation frequency at the doubling dose is by definition double the frequency of spontaneous mutation. If a threshold existed below the lower limit of the experimentally demonstrated linear portion of the dosage curve, the curve would have to follow the heavy dotted line. This would imply that the lowest applied doses produced no mutations, and then a short region of increasing dose would yield mutations with an efficiency significantly exceeding that of the long linear portion of the dosage curve. For physical reasons this is very improbable. If any considerable portion of the spontaneous mutation is, for a particular species, induced by the background radiation, the entire curve, including the origin, would be shifted correspondingly to the right if the natural radiation were included with the applied in the definition of "dose." If the background radiation is not included in the "dose," the curve and its origin would be unaltered.

fective; and (b) there is no sign of a threshold dose below which mutations are not produced. Rather, even the lowest doses are proportionally mutagenic, and all doses, however distributed, are additive or cumulative in effect. These relations are further borne out by the evidence that differences in the energy of quanta are not significant in respect to point mutations. Whether the quanta are the extremely powerful ones of cosmic rays or the less energetic ones of gamma or roentgen rays, down to the weakest ionizing quanta of the grenz rays, the mutational effect remains linearly proportional to the ionization produced. Ionizing particles, such as beta rays (electrons), alpha particles, and neutrons are also effective in producing mutations, both of the chromosomal and of the submicroscopic sort. They show differences in efficiency, but the dosage relation for the point mutations is in each case one of linear proportionality.

Mutations also arise in all populations spontaneously. These, like the radiation-induced ones, are also in the great majority of instances harmful, although possibly not quite as universally as the radiation-induced ones, since spontaneous mutations may occasionally mutate back to the original form of the gene, but radiation-induced ones have rarely if ever been observed to do so. One can readily see why the effects of mutation are essentially irreversible. The loss of a part of the genetic material is irreparable, since the template is destroyed. Alterations of the genes are permanent because the new genes formed by the altered chromosome will be modelled on the altered genes. Only an exact reversion to the original state, a back-mutation commonly rarer than the original change, will accomplish a restoration of the former gene. Consequently, once a mutation has been produced by radiation and has been transmitted to the population, it continues its way from generation to generation until it is either eliminated by the death or failure of its possessor to reproduce, or is excluded by chance from representation in the progeny.

Radiation acts blindly, not selectively on certain genes and not on others, and that is why the deleterious nature of the vast majority of mutations is so important. By means of several hundred roentgens of radiation it might indeed be possible to increase the probability of obtaining a desirable mutation in a reproductive cell to a chance of 1 per 1,000. But mutations that produce a beneficial effect under existing conditions, or even those that produce a detectable change that is neutral in respect to viability and fertility, are a tiny minority among all mutations in general. Hence at the same time the probability of getting a lethal mutation, to judge from relative frequencies in Drosophila, would have risen to 1 in 4 gametes, and the probability of getting a mutation with some degree of harmfulness to virtual certainty.

It is particularly important to note that the reduction of fitness in the population because of its burden of harmful mutations carried until they are eventually extinguished is not primarily due to dominant genes, for these are quickly eliminated, and usually so early in pregnancy as to produce little harm. Nor is it attributable to the rare occurrences of the recessive harmful mutations in double dose. Most of the mutational load is, as Crow[2] puts it, "due primarily to detrimental recessive genes that have small but not negligible effects as heterozygotes [and] cause no obvious visible abnormalities . . . for most of the genetic damage, if we can analogize from Drosophila, is due to genes that cause a slight reduction of life expectancy, a decrease in fertility, an increase in various kinds of ordinary illnesses, and other such non-specific effects."

Because of spontaneous mutation, a certain load of mutations exists in the population, at an equilibrium set by the mutation process that feeds in new mutations of each kind, and the selective process that eventually eliminates each mutation that reduces viability or fertility. Were the mutation rate to be permanently doubled, a new equilibrium would eventually be at-

tained at frequencies of the undesirable genes just twice as high as before.[2] Hence, a radiation dose that exactly doubles the spontaneous mutation rate—the so-called "doubling dose"—would eventually, after ten to forty generations, double the human burden of defects attributable to harmful genes. The National Academy of Sciences Genetics Committee[3] stated in 1956 that 4 to 5 per cent of all live births in the United States represent defects of a tangible sort such as "mental defects, epilepsy, congenital malformations, neuromuscular defects, hematological and endocrine defects, defects in vision or hearing, cutaneous and skeletal defects, or defects in the gastro-intestinal or genito-urinary tracts . . . of all of these, perhaps about half—or 2 per cent of the total live births—have a simple genetic origin. . . . " Each year approximately 4 million live infants are born in this country. Thus 80,000 annually, in round figures, have tangible defects of a hereditary nature. A doubling dose would increase this to an eventual annual total of 160,000 genetic defectives born, with perhaps an increase of 10 per cent, or 8,000, annually during each of the 30 years of the first generation.

It is obvious that it would be helpful, from the standpoint of an evaluation of the effects of radiation, to know the exact magnitude of this doubling dose—not, of course, that smaller doses would not do proportionate genetic damage. If all the spontaneous mutation were caused by the background radiation (cosmic rays, atmospheric radiation, radiation from rocks, soil, and housing, and internal radioactivity of the body), then the doubling dose would be equal to the background radiation. In the United States and Great Britain, according to latest estimates,[4] this averages 3.1 rem; although in certain areas of the world it may be considerably greater. But we know that for Drosophila not more than 1/1000 of the spontaneous mutation is attributable to the background.[5] Allowing for man's greater reproductive lifetime—approximately 365 times as long as the fruit-fly's—it seems very unlikely that the doubling dose can be less than 10 r per generation. This dose, of course, is that to the gonads. On the other hand, in various organisms studied by geneticists fairly thoroughly, the doubling dose seems to fall within the range of 40 to 80 r. This range has been taken by both the American and British Committees[3,6] on the genetic effects of radiation as bracketing the most probable values.

It may be instructive, therefore, to calculate the number of tangible genetic defects and the total number of harmful mutations to be expected from the estimated medical and dental exposures to radiation in the United States, assuming an annual birth rate of 4 million, and three possible values of the doubling dose. The medical and dental diagnostic and therapeutic exposures of the gonads have recently been estimated by Laughlin and Pullman[7] from an extensive survey of the medical literature. It is true that many of the data on which the estimates are based are limited to particular institutions or situations, that there is very great variation in actual practice, and that the statistical uncertainty of the estimates is great. The authors recognize this. Nevertheless, no better estimates can be made at the present time from available data; and they are in agreement with very similar estimates of the exposure of the Swedish population to diagnostic roentgen rays. Two values are given by Laughlin and Pullman: a *minimum gonad dose* computed on the basis of the lowest gonadal doses reported, and a *probable gonad dose* based on an average of those reported measurements of techniques generally employed. The former is 2.0 ± 1 r and the latter is 4.6 ± 3 r. It may thus be concluded that the current gonadal dose to the population of the United States per generation is not likely to be less than 1 r or more than 8 r, and may well be 4 or 5 r. This would represent an annual gonadal dose of 1/30 to 8/30 r (33.3 to 266.4 mr). As the most probable estimate I shall take the round figure of 1/6 r (167 mr) per year. This cer-

tainly would not initially strike anyone as an alarming dose.

The limiting ratios of the medical-dental gonadal dose to the doubling dose are 1/80 (1 r:80 r) and 8/10 (8 r:10 r). The most probable ratio would appear to be 1/10 (1 r:10 r or 8 r:80 r). Using these values, one can estimate that the increase in tangible genetic defects of the kinds mentioned above, in an annual number of 4 million births, would eventually amount to between 1,000 and 64,000 defective babies, the most probable number being 8,000. Of these, one would expect to find annually over the first generation (30 years) perhaps 10 per cent, that is, 100 to 6,400 defectives, the most probable estimate being 800. These numbers are clearly not negligible and must cause great concern. Nevertheless, they must be seen against the background of the 80,000 annual births of genetic defectives attributable to the spontaneous mutation rate. Even over the long term, this is but a 10 per cent increase.

Next let us estimate the total increase in undesirable mutations on the basis of the same assumptions. The spontaneous mutation rate accounts for perhaps 120 mutations per locus in 4 million births; 320,000 mutants of the class causing an increased probability of death between birth and adulthood, including stillbirths; and perhaps 1,200,000 causing an increased probability of death from the time of conception (calculated from Ref.[2]). The rate of induced mutations per roentgen we estimate at 20,000 in 4 million births, or 2 mutations per locus. The range of uncertainty is vast, extending over one order of magnitude on either side of the estimate given. With this estimate of the mutation rate per r, and three estimates of medical-dental gonadal dose per year (minimum, probable, maximum), it is obvious that the estimated values for the total mutation rate will vary over several orders of magnitude. However, taking the most probable estimate for each parameter, the total number of harmful mutations estimated to be induced by the annual medical-dental diagnostic and therapeutic gonadal dose is 3,333 mutations in 4 million births. Since each generation is estimated at 30 years, the annual exposure of the entire population at this rate for 30 years would lead to a rate at the end of such a term of 100,000 mutations in 4 million births. The number of these "genetic deaths" expected to occur annually would rise from perhaps 200 in the first year to about 6,000 in the thirtieth year, and would continue to increase thereafter as long as the exposure also continued, until the upper limit of about 100,000 mutations annually was reached.

Table 1

ESTIMATES OF HARMFUL MUTATIONS INDUCED BY THE ESTIMATED CURRENT LEVEL OF MEDICAL AND DENTAL EXPOSURES TO RADIATION IN 4 MILLION ANNUAL BIRTHS, IN THE UNITED STATES. (Calculated from Ref. [2])

	Annual Increase in No. at End of 30 Years	Annual Increase in N_Q at Eventual Equilibrium
Achondroplasia	10	12.5
Gross mental or physical defect	800	8,000
Infant and childhood death	1,920	32,000
Embryonic and early childhood deaths	4,560	76,000
Total harmful mutations = "genetic deaths"	6,000	100,000

Table 1 shows the estimated increase for other categories of genetically produced defect, from a single dominant mutant gene causing achondroplasia to the total "genetic deaths."

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BONE, SKIN, AND GONADAL DOSES IN ROUTINE DIAGNOSTIC PROCEDURES*

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FOR many decades members of the American Roentgen Ray Society and of other radiologic societies have been concerned with the safe use of radiation and have instigated research and the formulation of regulations to insure the safe use of radiation in medical procedures. This symposium is a reflection of the continuing interest and of the importance which this Society obviously attaches to the safe use of radiation in its profession. During the past decades, as a result of the efforts of radiologists and at their insistence, diagnostic procedures, while becoming more varied, have been developed with more protection and less undesired radiation. Radiologic physicists and roentgen-ray equipment manufacturers have participated in these efforts.

From the radiologic physicist's point of view, it should be emphasized that the most constructive and interesting problems in diagnostic radiology include developments to increase the variety of techniques available to the radiologist. These include the use of isotopes, miniature roentgen-ray tubes, high voltage roentgen rays, and developments to increase resolution, sensitivity and contrast. With the introduction of image amplifiers, fast developers, and more sensitive films, the radiologist is continuously improving his equipment in the direction of better diagnosis with less radiation exposure. By their nature many of these developments can be made only by industry with its large resources for research and development. Radiation safety problems and improvements are also important and interesting, though they will normally occupy only a part of the hospital physicist's time and effort.

As the title indicates, this paper deals with radiation exposure associated with some diagnostic procedures. The points to be discussed include methods of measurement of radiation dose along with phantom description, the amount of radiation received naturally which constitutes a base line reference, a survey of reported measurements in the literature on the radiation dose incident to diagnostic procedures, presentation of some of our own measurements, and a brief consideration of the assumptions necessary in estimation of the general population gonad dose on the basis of the present limited data.

MEASUREMENT OF RADIATION DOSE

With respect to the measurement of radiation exposure, several parameters should be defined. The first parameter is the quality of the radiation. The quality of the useful beam from a diagnostic machine can be characterized approximately by means of absorption curves in air. The use of proportional counters or scintillation crystals and associated pulse height electronic apparatus now makes it possible to measure the spectra precisely. However, radiation at various points within the human body may include different possible components such as: (a) degraded radiation in the useful beam, (b) scattered radiation from points in the body which are in the useful beam, and (c) stray radiation which may be either leakage radiation through the tube housing or scatter from other points in the room. The quality of the scattered

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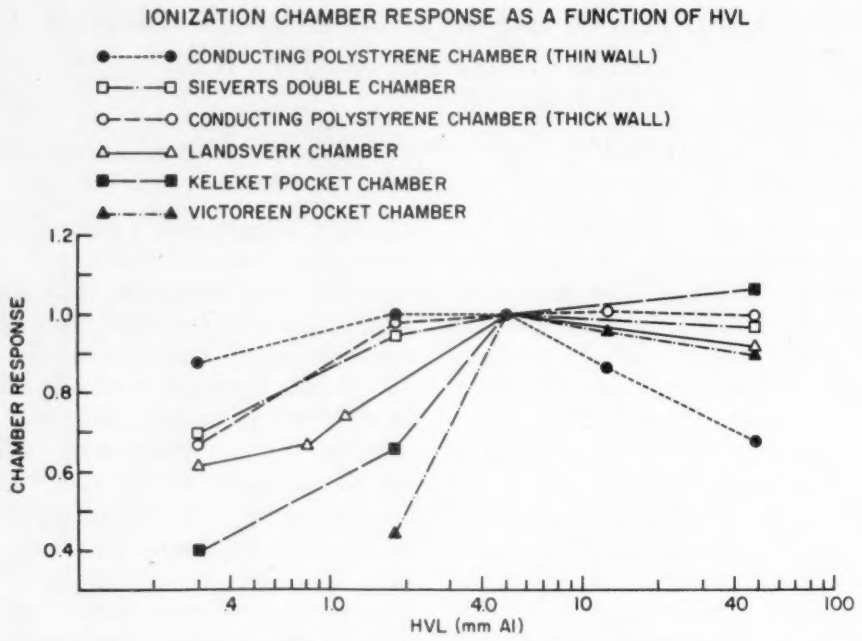

FIG. 1. The response of several chambers relative to the roentgen is shown for qualities of radiation extending from 0.3 mm. Al half value layer to 2 mm. Cu half value layer. The plots above are for specific individual chambers and are not necessarily applicable to other chambers of the same manufacture. In fact, it is necessary to make such determinations for every chamber employed. All of the chambers identified are made for a specific purpose and this plot is in no way a reflection on their merits.

and degraded radiation at points outside the useful beam has not been directly measured though we are now commencing to do this. In the meantime we can only make estimates of the amount of decrease in effective energy at various points in the body associated with an incident beam of a given quality.

The next parameter which must be considered is the response of the radiation detector to different qualities of radiation. If one had a detector the response of which either in exposure dose in roentgens or absorbed dose in rads were constant regardless of the quality of the scattered roentgen rays and electrons, the knowledge of the quality of the radiation mentioned above would cease to be of major significance. It is, therefore, of the greatest importance to know the response of the radiation detector being employed to different qualities of radiation. Figure 1 illustrates the response of a variety of chambers as a function of radiation quality. The ordinate is the ratio of the reading of the chamber to the exposure dose in roentgens. Both the chamber response and the exposure dose are determined in air. The abscissa indicates the half value layer of the radiation being employed. Most miniature chambers commercially available are particularly designed to have a uniform response in the upper diagnostic and therapy regions and have a depressed response for the softer qualities of radiation as indicated on this graph. By special design it is possible to make chambers which have a relatively uniform response in the diagnostic region which we may consider here as being that region from essentially 3 mm. aluminum half value layer on down. The graph illustrates the improved response of a chamber with homogeneous walls of conducting polystyrene. This wall avoids the problems of flaking of the conducting coat and avoids an effective change in the wall atomic number for different qualities of radiation. A variety of chamber dimensions, different wall thicknesses,

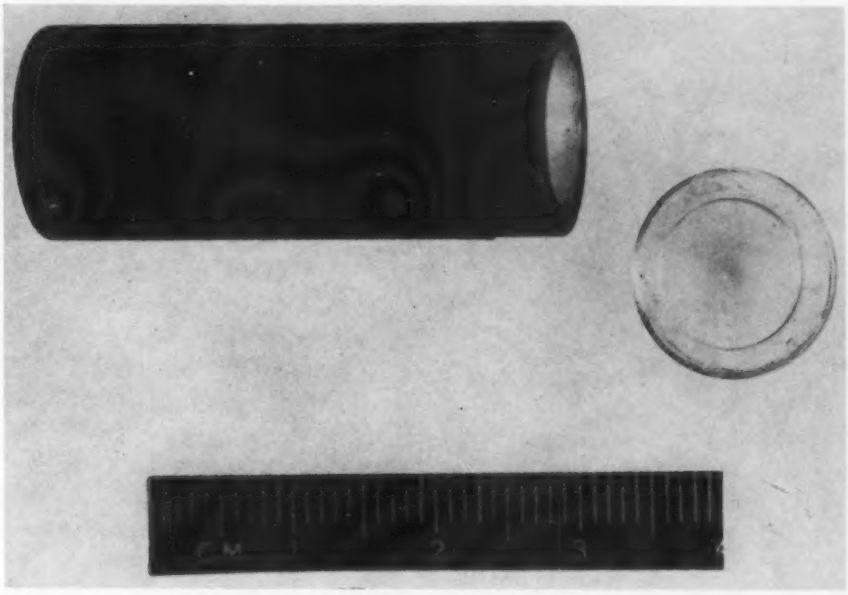

FIG. 2. View of miniature condenser chamber with wall of conducting polystyrene and aluminum electrode. The wavelength response of this chamber is shown in Figure 1.

electrodes of different materials and dimensions have been investigated. At present we are using a relatively large aluminum electrode and with this arrangement obtain the superior wavelength response indicated. Figure 2 shows a photograph of this chamber. This is a condenser type version which is charged on the Farmer-Baldwin radiologic electrometer, though it is also being made as a part of a continuously reading probe apparatus. Since most diagnostic units can be operated for only short lengths of time, the condenser type version is usually the more useful. When conditions can be simulated with a continuously operated roentgen-ray machine, particularly for shielding tests, the continuous probe type chamber becomes more advantageous.

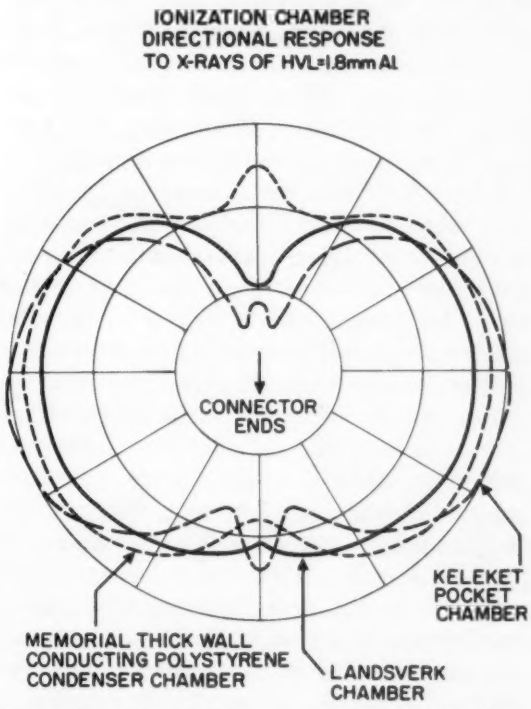

FIG. 3. Directional response of miniature chambers. The direction of the long axis of each chamber is indicated by the arrow. Relative response is plotted uniformly along the radii.

Figure 3 illustrates another parameter which must be considered: the directional response of chambers. In the calibrations shown in Figure 1, the long axis of each was normal to the axis of the roentgen-ray beam, which is the orientation in which most chambers have a more uniform directional and also their maximum response characteristic. As shown, for commercial chambers and somewhat for our own chamber there is a pronounced directional de-

FIG. 4. Phantom of young adult body. Unit density pressdwood has been employed. An entire skeleton (which shows white in the section) has been inserted in the pressdwood. The lungs are represented by cork of 0.3 gm./cc. density. Air cavities are also present. The skeleton was impregnated with beeswax as were the spaces between it and the pressdwood. The phantom is laminated in 3 cm. thick sections which permits disassembly at any desired location, and also permits adjustment of vertical dimensions of the body.

pendence. This is minimized by making the diameter and length comparable.

Another parameter which must be considered and which is particularly important for pulsed diagnostic exposures is that of saturation effects. The voltage applied on the chamber must be sufficiently high so that essentially all ions are collected before recombination can occur. This can be tested by calibrating the chamber at a variety of dose rates including those which exceed any in use with the diagnostic apparatus. It can be further cross-checked in use with the diagnostic apparatus by comparisons with larger chambers the saturation properties of which are well known.

The next problem to consider in the measurement of radiation exposure is the body itself. Significant testes measurements can be made on patients, but cadavers or phantoms are most convenient for ovary measurements. Significant ovarian dose estimates have also been made by insertion of chambers into the posterior fornix of the vagina. However, in addition to ovaries and testes, there are other locations of importance. We have been particularly concerned with the dose delivered to the blood forming marrow in the bone. This requires insertion of the chamber in the bone which is difficult even in a cadaver. For this reason we have constructed and have used in our own measurements a phantom which is shown in Figure 4. This phantom consists primarily of unit density pressdwood into which a wax impregnated skeleton has been inserted. The pressdwood was cut out to allow the insertion of all of the bones in the skeleton. The marrow, which has been removed, was replaced with pure beeswax of 0.97 gm./cc. density. The spaces around the bone in the pressdwood were also filled with beeswax. The lung was simulated with cork of density 0.3 gm./cc. Some of the lung simulated with cork as as well as some of the bone can be seen in this photograph. Figure 5 shows roentgenograms of this phantom, and chamber positions are indicated by the shadows of steel rods. We have employed two testes positions, two ovary positions, and three positions along the spine in the vertebrae in past measurements. More bone marrow positions in femoral head, pelvic bone, and sternum have been subsequently added. It is believed[11,12,35] that in young adults from twenty years on the vertebrae, sternum, clavicles, scapulae, skull, and ribs are normally the most important regions of blood formation. Of course, if activity in these is depressed due to radiation or other insults, the femur or tibia can be called into service. This phantom is also laminated so that it is possible to change its vertical dimensions, which is important in considering the roentgenography of different sizes of adults, and also for convenient access to the chambers without the necessity of drilling external holes through the trunk. Smaller size phantoms are under construction to cover other age groups where the smaller dimensions make the exposure problems quite different. Also, in children both the femur and tibia contribute appreciably to blood formation.

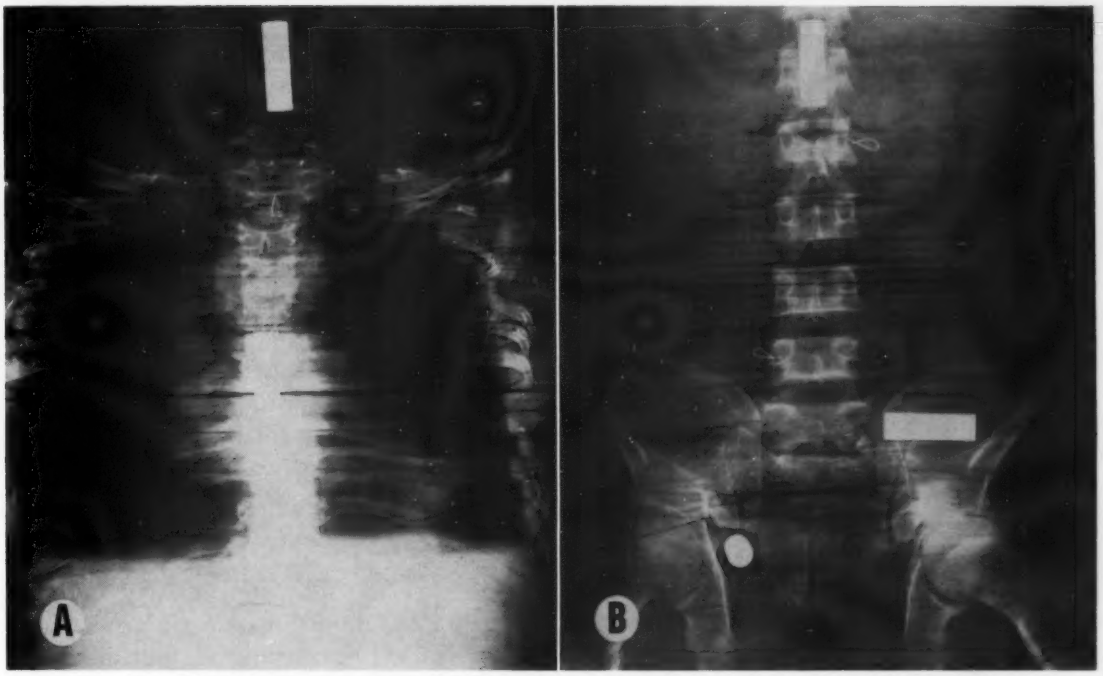

Fig. 5. (*A* and *B*) Posteroanterior roentgenograms of phantom. Some of the chamber positions are indicated by steel rods.

There has been some interest in the total dose absorbed by the body incident to radiation exposure. This has been calculated by Ritter, Warren and Pendergrass[29] for various diagnostic procedures, and also by Feddema and Oosterkamp.[13] This quantity can also be measured directly by determination of the oxidation of the ferrous ion in solution in phantoms which represent the body. The integral dose measured in this manner for diagnostic roentgen rays with different amounts of filtration was reported by Meurk *et al.*[23] This study showed, as expected, that as the filtration of the diagnostic roentgen-ray machine was increased, the exposure dose in air decreased drastically even though the length of the exposure was normalized for the same film density. The saving in skin dose was not as marked as the saving in air dose, and the decrease in integral dose as measured by the oxidation of ferrous sulphate was even less marked. However, the saving was appreciable and well worthwhile. The total integral dose is probably not as significant in radiation damage considerations as the bone dose.

NATURAL BACKGROUND DOSE

Before reviewing the diagnostic exposure doses, the natural background dose is described in order to provide a basis for comparison. All of us are exposed continuously to radiation. This radiation is contributed primarily by three different sources: cosmic rays, radioactive elements in the earth, and internal radioactivity.

Primary cosmic rays are positively charged particles which reach the earth from interstellar space. They consist primarily of protons, about 85 per cent, with the remainder consisting of alpha particles and a few heavier charged nuclei. Most of these primary particles are in the several billion electron volt energy range with some much more energetic. Because of the deflection of these charged particles by the earth's magnetic field, more of them enter near our magnetic poles than near the magnetic equator. For instance, the rela-

tive number per square centimeter of outer atmospheric surface is about ten times greater at a latitude of 52° than at the equator. These primary positively charged particles interact with the atmosphere to produce secondary particles which consist of mesons, protons, electrons, roentgen rays, and neutrons. Below about 50,000 feet there are essentially none of the primary particles left. On the basis of ionization measurements made in the New York City area, in England, and in Holland, the air dose is approximately 26 millirads per year. Because of the high energy of this radiation the internal dose at any internal body point such as the bone and gonads will be essentially the same as the air dose.

Earth and housing materials all contain naturally radioactive material in the form of radium, uranium, thorium, and potassium 40. On the basis of ionization measurements in the New York City area over sedimentary soil by Hess[17] and co-workers, the air dose ranges from 25 to 60 millirads per year. The air dose rate inside brick and concrete buildings[19,31] and our sidewalks is higher, from 70 to 160 millirads per year. These dose rates are weighted by the estimated urban and suburban fraction of the population. When corrected for attenuation by the body for both adults and children, a resultant gonad dose is obtained which is about twice that due to cosmic radiation. A small amount of additional exposure is due to atmospheric radioactivity consisting primarily of gaseous radon and thoron which diffuse into the atmosphere from earth. Ionization measurements indicate this to be about 10 per cent of the contribution from cosmic rays.

We are also being continually insulted by radiation originating from naturally radioactive atoms in our own body. Potassium 40, carbon 14, and radium are the largest contributors. Considering the increased biologic effectiveness of the alpha particles from radium, the contribution of internal radioactivity is essentially equal to that of cosmic rays. As shown in the summary in Table 1, natural background radiation from these various sources produces a gonadal dose of approximately 100 millirem per year.

Since we are also concerned with bone marrow dose due to diagnostic procedures, it is pertinent to consider the natural background contribution to marrow dose. Cosmic rays are sufficiently energetic that the absorbed dose they produce in bone marrow should be essentially the same as in the gonads. For earth and housing the air dose rates have been reduced by a factor of 0.75 for attenuation by the bone and overlying tissue. As above, allowance is made for urban and suburban populations and an estimated dose of 59 millirads per year is thus obtained. The small carbon 14 contribution is assumed the same but the potassium 40 contribution is reduced in bone. Assuming a uniform distribution in the skeleton of a radium burden of

TABLE I

ANNUAL NATURAL BACKGROUND DOSE

Source of Radiation	Gonadal		Bone Marrow	
	millirads/year	millirem/year	millirads/year	millirem/year
Cosmic Rays	26 ± 3	26± 3	26 ± 3	26± 3
Earth, Housing	53 ±20	53±20	59 ±20	59±20
Atmospheric	2 ± 1	2± 1	—	—
Internal Radioactivity				
Beta and Gamma Rays	18 ± 3	18± 3	5 ± 1	5± 1
Alpha Particles	0.5± 0.3	5± 3	4.5± 2	45±20
Total		104±21		135±30

1.18×10^{-10} gm.[20] we have a bone dose of 44.7×10^{-4} rads per year, or 0.045 rem per year assuming alpha particles have a relative biologic effectiveness of 10. The result is about 135 millirem per year in the bone marrow assuming uniform distribution.

REPORTED RADIATION DOSES FOR DIAGNOSTIC PROCEDURES

The literature has been surveyed and published estimates and measurements of skin and gonadal dose are summarized briefly here. Material in the Preliminary Report: Gonadal Dose from the Medical Use of X-Rays,[27] a comprehensive technical report prepared for the Genetics Committee of the National Academy of Sciences' Study of the Biological Effects of Atomic Radiation has facilitated preparation of this survey. This summary is presented to provide an idea of the magnitude of the radiation doses (primarily skin and gonadal) associated with various diagnostic procedures. As will be apparent from study of these tables, not all diagnostic techniques have been adequately studied; the reported doses often cover a wide range, and the full details of the measurement (or calculation) are not always described. Much of this spread is due to variations in the techniques employed in the various diagnostic clinics.

The authors do not believe it is realistic to present a simple list of diagnostic procedures each with its own specific and single value of associated gonad dose, with the idea that such a list will have general applicability. The inherent and large variation in procedures among different clinics, and even within a department, precludes this. Of course, it is possible to make measurements or calculations which apply with precision to a given technique under specified conditions. More useful is a range of values for a given technique extending from the minimum possible up to values more representative generally.

In the tables which are included the examination is ordinarily roentgenographic, unless fluoroscopy is designated. Values are also ordinarily for single films. The added filtration, when specified, is given in millimeters of aluminum. Kvp. refers to the peak kilovoltage while mas. represents milliampere-seconds. The doses are always

TABLE II

RADIATION DOSE (mr) IN EXAMINATION OF THE PELVIS

Reference No.	Type of Examination	Skin Dose	Testes Dose	Ovary Dose	kvp.	mm.Al	mas.	Remarks	Authors
8	Pelvis, anteroposterior	500	550	200	66		100		Billings *et al.*
	Pelvis, anteroposterior	350	350	155	120		16	High voltage	
29	Pelvis, anteroposterior	5,300		600	58	1	420		Ritter *et al.*
	Pelvis, lateral	21,000		2,800	74	1	750		
21	Pelvis, anteroposterior	1,300				2			Kirsh
16	Pelvis, anteroposterior	1,100			60	0.5	10		Handloser and Love
32	Pelvis, anteroposterior	4,700	1,100	210	65	0	100		Stanford and Vance
22	Pelvis, anteroposterior		140–2,600	50–700					Martin
	Pelvis, anteroposterior			20–170				High voltage	
	Pelvis, lateral			1,400–1,700					
	Pelvis, lateral			220–1,500				High voltage	
2	Pelvis, anteroposterior	480	20	80	75	3	80	Lead rubber shield over testes	Ardran and Crooks

TABLE III

RADIATION DOSE (mr) IN PELVIMETRY EXAMINATION

Reference No.	Type of Examination	Skin Dose	Fetal Dose	Ovary Dose	kvp.	mm.Al	mas.	Remarks	Authors
29	Pelvimetry, anteroposterior	5,000	400	400	65	1	300		Ritter *et al.*
	Pelvimetry, lateral	26,700	1,300	3,500	78	1	780		
	Pelvimetry, inlet	14,000	900	400	75	1	420		
6	Pelvimetry, lateral		1,200						Berman
	Pelvimetry, inlet		400						
	Pelvimetry, outlet		400						
30	Pelvimetry			2,100–2,900				Four films	Sonnenblick
26	Pelvimetry, lateral	120,000	6,000		80		400		Osborn
	Pelvimetry, oblique anteroposterior	50,000	3,000		80		400		
	Pelvimetry, lateral	120,000	30,000		80		400	Vertex presentation, male fetus	
	Pelvimetry, oblique anteroposterior	50,000	15,000		80		400	Vertex presentation, male fetus	
33	Pelvimetry, lateral	8,000–20,000	400–1,000	230–1,300	84		400–750		Stanford
	Pelvimetry, oblique anteroposterior	16,000–30,000	1,000–1,800	230–1,300	84		600–1,200		
	Pelvimetry, lateral		2,000–5,000					Vertex presentation, male fetus	
	Pelvimetry, oblique anteroposterior		5,000–7,000					Vertex presentation, male fetus	
24	Pelvimetry, lateral	36,500		3,700	82		400		Moloy and Swenson
	Pelvimetry, anteroposterior	8,400		1,400	82		40	Two films	
	Pelvimetry, anteroposterior 45°	1,400		200	82		60		
14	Pelvimetry, lateral	40,000		4,200	85		450		Haas *et al.*
	Pelvimetry, anteroposterior	14,000		3,000	85		100	Two films	
	Pelvimetry, anteroposterior 45°	1,500		300	85		60		
7	Pelvimetry, lateral	5,800	100	100	120	1	75		Bewley *et al*
	Pelvimetry, inlet	11,500	2,800	20	120	1	130		
	Pelvimetry, outlet	2,600	500	30	108	1	75		
9	Pelvimetry, lateral			60–2,250	85	1	300	Fetal gonads outside primary beam	Clayton *et al.*
	Pelvimetry, outlet			210	72.5	1	160	Fetal gonads outside primary beam	
	Pelvimetry, inlet (Thom)		3,000	1,400	80	1	400		
	Pelvimetry, inlet (modified Thom)			400	80	1	200	Fetal gonads outside primary beam	

in milliroentgens (mr). For the practical purposes of radiation safety these may be considered equal to millirads and millirem.

Pelvis. In Table II there are collected some of the published measurements and calculations for roentgenography of the pelvis. Billings, Norman, and Greenfield[8] employed a wooden phantom into which calibrated Victoreen thimble chambers were inserted in ovary and testes positions. The locations of the ovaries were specified as 9 cm. below the surface in the mid-frontal pelvic plane, 11.5 cm. above the pubic symphysis, and 4.5 cm. from the midline on each side. The testes measurements were made at the caudal midpoint of the trunk phantom 2.5 cm. beneath its anterior surface. Filtration and film type are not specified. They demonstrate some advantage with the use of high voltage. Ritter, Warren, and Pendergrass[29] reported a comprehensive series of measurements of expo-

sure dose-rate for a large variety of techniques. They measured the output in air, and calculated skin dose and the depth dose at 10 cm. with the aid of specified tables. Their paper also contains integral dose calculations, absorption curves for different qualities of diagnostic roentgen rays, and other useful information. Kirsh[21] has reported chamber measurements on the skin of patients, and also on the scrotum for other techniques. Handloser and Love[16] have reported skin dose measurements for a variety of techniques. Stanford and Vance[32] employed calibrated chambers which they placed on the scrotum in males. For females they measured the ratio of ovary dose to surface dose in cadavers and made surface dose measurements with patients.

Martin[22] has reported a survey of diagnostic techniques based both on his own measurements and also on calculations. He employed ionization chambers placed in contact with the scrotum, and for females a chamber was either placed in the posterior fornix or on the skin above the ovaries, and depth dose data were used to estimate the ovary dose. His results emphasize the advantage of high voltage techniques. Ardran and Crooks[1,2] have made measurements for a variety of techniques. They employed calibrated miniature ionization chambers on the scrotum for male gonadal doses. They also employed a phantom of Mix D 9 inches thick to represent an average patient. They used chamber measurements midway through the phantom for ovary dose values. In their techniques they employed heavy filtration, fast film, small fields, and scrotum shields. Their results probably represent the minimum doses possible at the time the measurements were made.

Table II displays testes doses for anteroposterior roentgenography of the pelvis which range from 20 mr to 2,600 mr per film, and ovary doses from 50 mr to 700 mr. Ovary doses from 220 mr to 2,800 mr are reported for the lateral view. The advantages of the use of higher voltage or heavy filtration, small fields, fast film, and scrotum shields are particularly apparent for this type of examination.

Pelvimetry. Table III summarizes most of the reported measurements or estimates of fetal gonad dose and ovary dose for pelvimetry examinations. As described above, Ritter *et al.*[29] measured air doses and calculated the dose at specified depths. Sonnenblick[30] employed calibrated chambers in the posterior vaginal fornix. Berman[6] used a calibrated thimble ionization chamber to make measurements of the fetal head. Haas *et al.*[14] employed a Victoreen thimble chamber on the skin and against the cervix for their measurements. Bewley *et al.*[7] constructed two plaster casts of different sizes modeled on patients. Wires were mounted inside for anatomic reference and the casts were filled with bolus. Ionization chambers were located superficially and internally and a correction was applied for the attenuation by the plaster. Ilford Red Seal film, high kilovoltage screens, and restricted field sizes were employed. Clayton *et al.*[9] measured the dose at carefully specified points in a water phantom to obtain ovary and fetal doses.

Comparison of the results in Table III indicates that the techniques described by Bewley *et al.* produced maternal ovary doses approximately an order of magnitude lower than those produced by more conventional techniques. Their reported fetal doses were also significantly less than most. Assuming the film quality is adequate for diagnosis, this comparison emphasizes the importance of field size limitation, angulation to avoid the fetal gonads, and the use of fast film and high voltage.

Intravenous Pyelography. The results of the comprehensive analysis of diagnostic procedures by Ritter *et al.*[29] which are applicable to intravenous pyelography are presented in Table IV normalized to four films. Weens *et al.*[34] have employed miniature ionization chambers in the vaginal fornix of patients for a variety of procedures. The chambers were calibrated by comparison with a large calibrated thimble

TABLE IV

RADIATION DOSE (mr) IN UROGRAPHY (NORMALIZED TO 4 FILMS)

Reference No.	Type of Examination	Skin Dose	Testes Dose	Ovary Dose	kvp.	mm.Al	mas./film	Remarks	Authors
29	Intravenous Pyelography	5,200		650	62	1	100		Ritter *et al.*
34	Intravenous Pyelography			200	74–88		20–40		Weens *et al.*
21	Intravenous Pyelography	6,800	1,200			2			Kirsh
28	Intravenous Pyelography	5,000 (air)				1	100		Poppel *et al.*
22	Intravenous Pyelography Bladder Kidney		560 790 10	1,000 600 120					Martin
2	Bladder	1,920	40	320	75	3	80	Testes protected by lead rubber	Ardran and Crooks
	Kidney	1,920	2	380	75	3	80		
32	Bladder	3,330	124	306	72	0	100		Stanford and Vance
	Kidney	3,330	92	267	72	0	100		
18	Urographic Survey		160	880	72	2.5	100		Hol and Koren
	Urographic Survey		60	360	120	2.5	13		
	Urography, bladder		400	1,120	72	2.5	100		
	Urography, bladder		160	440	120	2.5	13		
	Urography, kidney			96	72	2.5	100		
	Urography, kidney			48	120	2.5	13		

chamber in the useful beam (presumably in air) for the quality of incident roentgen rays employed. Their value is the lowest reported. Kirsh[21] has reported direct measurements on the scrotum of male patients for added filtration of 0, 1, and 2 mm. Al. For four films with 2 mm. Al he observed a skin dose of 6,800 mr and a testes dose of 1,200 mr for intravenous pyelography. Poppel *et al.*[28] have reported an air dose of 5,000 mr for four films.

Martin[22] employed calibrated chambers on the scrotum, and in the case of females he measured the skin dose and calculated the ovary dose. His results on a four film basis are testes 5,000 mr and ovaries 1,000 mr. Stanford and Vance[32] reported values in essential agreement. Ardran and Crooks[2] have also recently reported values for this procedure based on the use of calibrated chambers on the scrotum of patients, and skin dose measurements for females. The reduced testes values are due primarily to the use of a lead rubber shield. Hol and Koren[18] have compared high and low voltage techniques for a urographic survey film (multiplied by 4 in Table IV) and for kidney and bladder spot films. Their high voltage results are in reasonable agreement with those of the English authors; their kidney values are the lowest reported. They employed a restricted field size and reported that the testes values increased by a factor of 8 when a wide field was employed.

For retrograde pyelography specifically we have not seen any measurements for the United States, but no major differences would be expected. Martin[22] has reported a testes dose of 700 mr for 2.9 films and an ovary dose of 800 mr for 3.7 films. However, there are data for Denmark[15] which indicate higher doses for retrograde pyelographic examinations than for the intravenous procedure, though the numbers of films may not have been the same.

Urethrocystography. No measurements are reported for this technique in the United States. Hol and Koren[18] have reported a testes dose of 550 mr for 72 kv. and 110 mr for 120 kv. Other Scandinavian

TABLE V

RADIATION DOSE (mr) IN EXAMINATION OF THE STOMACH AND UPPER GASTROINTESTINAL TRACT

Reference No.	Type of Examination	Skin Dose	Testes Dose	Ovary Dose	Technical Factors	Remarks	Authors
34	Fluoroscopy Spot films			100– 300	85 kvp. 2.5 mm.Al	Upper gastrointestinal tract	Weens *et al.*
5	Fluoroscopy	124,000– 205,000	5 cm. depth 10 cm. depth	19,000– 65,000 6,500 24,000		Upper gastrointestinal tract	Bell
	Roentgenography—6 films	6,500	5 cm. depth 10 cm. depth	2,250 820	80 kvp. 0.5 mm.Al 150 mas. total		
8	Roentgenography—1 film	360	0	0– 50	120 kvp. 20 mas.	Stomach	Billings *et al.*
29	Roentgenography, postero-anterior and oblique	1,000 1,400	Center of Abdomen— 3,000		65–69 kvp. 1 mm.Al 75 mas.	Stomach and duodenum 8 spot films, 5 serial films, 10 min. fluoroscopy	Ritter *et al.*
	Fluoroscopy, 10 min.				80 kvp. 1.5 mm.Al		
28	Roentgenography, 8 antero-posterior, 6 oblique and 1 lateral	20,000			1 mm.Al 1,275 mas.	Upper gastrointestinal tract	Poppel *et al.*
22	Fluoroscopy, 2 min. Roentgenography, 1 film	15,000		10– 1,100		Upper gastrointestinal tract	Martin
			180	150		Stomach	

values[15] range from 4,000 mr to 8,000 mr for the testes and from 300 mr to 669 mr for the ovaries for examinations consisting of several films.

Hysterosalpingography. Billings *et al.*[8] have reported phantom measurements for salpingography. They employed a wooden phantom of unit density into which calibrated chambers were inserted. Per exposure (62 kv.—100 mas.) they observed a skin dose of 500 mr and an ovary dose of 200 mr. Martin[22] has reported 2,500 mr ovary dose for a total examination. Barnett *et al.*[4] have reported doses ranging from 1,700 mr to 3,600 mr for a combination of fluoroscopy and roentgenography in hysterosalpingography.

Stomach and Upper Gastrointestinal Tract. Table v summarizes observations in the literature for both roentgenography and fluoroscopy. The range of values is great and indicates that with conventional techniques the ovaries, and also the testes when not shielded, will receive a few hundred mr in a complete series. The advantage of high kilovoltage is demonstrated by the results of Billings *et al.*[8]

Lower Gastrointestinal Tract. Table vi summarizes measurements made in both the United States and Great Britain. Fluoroscopy and roentgenography are indicated separately where possible. The data are few and scattered. It appears that, with conventional techniques, the gonads may be expected to receive a few hundred milliroentgens in a complete examination. However, the work of Stanford and Vance[32] and of Ardran and Crooks[2] indicates that the use of image intensification and testes shielding, etc., can reduce the fluoroscopic dose by an order of magnitude.

Abdomen. In Table vii the work of both

TABLE VI

RADIATION DOSE (mr) IN EXAMINATION OF THE LOWER GASTROINTESTINAL TRACT

Reference No.	Type of Examination	Skin Dose	Testes Dose	Ovary Dose	Technical Factors	Remarks	Authors
5	Fluoroscopy 1.5–4 min.	50,000–130,000	5 cm. depth 10 cm. depth	13,000–34,000 4,500–13,000		Colon, 75 cm.² field	Bell
34	Fluoroscopy			100–800	85 kvp. 2.5 mm.Al 530 mas.	Colon	Weens *et al.*
	Roentgenography				85–85 mas. 20 mas.	Spot films	
					72–98 kvp. 20–60 mas.	Large films	
29	Fluoroscopy, 5 min. Roentgenography		Center of Abdomen, 2,000			Barium enema 3 spot films 3 posteroanterior films	Ritter *et al.*
21	Fluoroscopy Roentgenography	4,900			2 mm.Al	Barium enema 2 spot films 2 large films	Kirsh
28	Fluoroscopy, 2 min.	15,000				Barium enema	Poppel *et al.*
	Roentgenography	11,800			1 mm.Al 600 mas.	Two anteroposterior, 4 oblique films	
22	Roentgenography		130	520		Barium enema, 3 films	Martin
32	Fluoroscopy	15,000	40	20	70 kvp. 360 mas.	Barium enema	Stanford and Vance
		15,000	20	9	70 kvp. 360 mas.	Barium meal	
2	Fluoroscopy, 5 min. Image intensification	1,500	5	5	75 kvp. 150 mas. 5 mm.Al	Barium meal	Ardran and Crooks

Billings *et al.*[8] and Ardran and Crooks[2] emphasizes the advantage of high kilovoltage or high filtration in the reduction of dose. Conventional techniques appear to produce an ovarian dose of approximately 100 mr to 200 mr whereas less than 100 mr can be obtained with the harder quality of roentgen rays.

Abdomen (*Obstetrical*). Table VIII summarizes the work from three laboratories in England. The values for both the ovary dose and the fetal gonad dose are seen to vary widely. Stanford and Vance[32] indicate that the use of high kilovoltage (comparison of 80 kvp. with 120 kvp.) reduces the skin dose by a factor of 2. Comparison of the lateral film values of the other two groups does not bear out the expected advantage of higher kilovoltage, which is due to other factors such as angulation and field size.

Bewley *et al.*[7] employed two phantoms formed of plaster casts as described above. Clayton *et al.*[9] employed a water phantom and an ionization chamber to measure dose at various pertinent depths.

Cholecystography. For this examination the data are also few and scattered (Table IX). Although an ovary dose of about 100 mr per film appears probable with conventional techniques, Stanford and Vance[32] have reported only about 5 mr to be possible. As emphasized in a recent article by Ardran,[3] such variation is to be expected

TABLE VII

RADIATION DOSE (mr) IN EXAMINATION OF THE ABDOMEN

Reference No.	Type of Examination	Skin Dose	Testes Dose	Ovary Dose	Technical Factors	Remarks	Authors
8	Roentgenography	460	0	155	62 kvp. 100 mas.	Comparison of conventional and high voltage exposure	Billings *et al.*
		210	0	75	120 kvp. 10 mas.		
29	Roentgenography	2,400			58 kvp. 1 mm.Al 210 mas.		Ritter *et al.*
28	Roentgenography	1,250			100 mas. 1 mm. Al		
32	Roentgenography	2,200	69	200	72 kvp. 0 mm.Al 100 mas.		Stanford and Vance
2	Roentgenography, anteroposterior	360	0.5	75	75 kvp. 3 mm.Al 100 mas.	Lead rubber shield over testes	Ardran and Crooks
	Roentgenography, anteroposterior	130	1.5	20	90 kvp. 3 mm.Al 20 mas.	Barium meal, prone	

and depends critically on field size and precise field location.

Chest. Measurements of the gonadal dose for chest examination are difficult because of the small magnitude and the degraded quality of the radiation. As seen in Table x the values cover a wide range and the relative magnitude of reported male and female gonadal dose is reversed for different observers. Even in the case of the much larger skin dose there is wide variation. These variations are due in part to the differences in technique such as amount of filtration, kilovoltage, angulation of cone, size of field, film speed, etc.

Possibly more important than gonad doses for chest examination is the dose received by blood forming cells. This is also discussed below.

Spinal Examination. Table xi summarizes reported data for examinations of the cervical spine, dorsal spine, lumbar spine, and the lumbosacral joint. Despite the appreciable skin doses, the exposure of the gonads can be held to low levels for dorsal spine examinations. In the case of the lumbar spine examinations, all of the data emphasize the advantage of heavy

TABLE VIII

RADIATION DOSE (mr) IN THE EXAMINATION OF THE ABDOMEN (OBSTETRICAL)

Reference No.	Type of Examination	Skin Dose	Fetal Dose	Ovary Dose	kvp.	mm.Al	mas.	Authors
7	Roentgenography, lateral	2,400	200	1,000	111	1	50	Bewley *et al.*
	Roentgenography, posteroanterior	1,300	150	200	99	1	50	
9	Roentgenography, lateral		100	20–450	67.5	1	120	Clayton *et al.*
	Roentgenography, posteroanterior		30	90	60	1	100	
	Roentgenography, anteroposterior		21	100	62	1	100	
32	Roentgenography	2,600		260	80	0	150	Stanford and Vance

TABLE IX

RADIATION DOSE (mr) IN CHOLECYSTOGRAPHY

Reference No.	Type of Examination	Skin Dose	Testes Dose	Ovary Dose	Technical Factor		Authors
29	Roentgenography, 3 posteroanterior, 1 oblique film		Center of Abdomen, 1,000		60 kvp. 1 mm.Al 150 mas.	Gallbladder	Ritter *et al.*
22	Roentgenography, 1 film Roentgenography, 1 film		 3	50 90		Gallbladder Cholecystography	Martin
32	Roentgenography, 1 film	2,600	0.6	5.2	70 kvp.	Cholecystography	Stanford and Vance

filtration or high kilovoltages. The use of lead rubber or other scrotum shields restricts the testes dose, but the ovary dose remains appreciable. For examinations of the lumbosacral joint, the ovaries receive a few hundred milliroentgens even with high voltage.

Dentistry. The results for dentistry will

TABLE X

RADIATION EXPOSURE (mr) IN CHEST EXAMINATION

Reference No.	Type of Examination	Skin Dose	Testes Dose	Ovary Dose	kvp.	mm.Al	mas.	Remarks	Authors
29	Posteroanterior	60			59	1	24		Ritter *et al.*
	Lateral	120			78	1	24		
	Oblique	70			63	1	24		
	Posteroanterior (Bucky)	220			64	1	36		
	Lateral (Bucky)	430			77	1	36		
16	Posteroanterior	50			72	0.5	20		Handloser and Love
21	Posteroanterior	31				2			Kirsh
	Lateral	400				2			
28	Anteroposterior, 1 film	190				1	55		Poppel *et al.*
	Lateral, 1 film								
	Anteroposterior (Bucky), 1 film	500				1	150		
	Lateral (Bucky), 1 film								
5	Fluoroscopy	16,500–65,000			70–84		180–720	16,500/min.	Bell
8	Posteroanterior	15	0	0	62		13		Billings *et al.*
	Posteroanterior, high voltage	30	0	0	120		0.7		
	Photofluorography		1	3					
	Posteroanterior	23	0	2	45		10	Babies	
32	Posteroanterior	160	0.36	0.07	68	0		Phototimed	Stanford and Vance
	Lateral	420	0.36	0.07	68	0		Phototimed	
	Laminagraphy	360	6.2	0.7	62	0	50		
	Photofluorography		0.25	0.15	83	0	24		
22			0.07–1.6	0.3 –8.9 0.12–0.6				High kilovoltage	Martin
2	Posteroanterior	8	0.01	0.02	90	3	3		Ardran
	Anteroposterior Laminagraphy	110	0.01	0.02	85	3	12		
	Fluoroscopy, Image intensification	900	3	3	75	5	90	3 min.	

TABLE XI

RADIATION EXPOSURE (mr) IN EXAMINATION OF THE SPINE

Reference No.	Type of Examination	Skin Dose	Testes Dose	Ovary Dose	kvp.	mm.Al	mas.	Remarks	Authors
29	Cervical Spine, anteroposterior	1,200			54	1	150		Ritter *et al.*
	Cervical Spine, lateral	400			64	1	150		
22	Cervical Spine		0.5	0.5					Martin
32	Cervical Spine, anteroposterior	1,500	0.27	0.06	58	0	100		Stanford and Vance
	Cervical Spine, lateral	1,100	0.92	0.20	70	0	150		
29	Dorsal Spine, anteroposterior	4,500			58	1	380		Ritter *et al.*
	Dorsal Spine, lateral	4,000			70	1	180		
	Dorsal Spine, lateral	6,000			58	1	480		
	Dorsal Spine, anteroposterior	2,700			64	1	210	Laminagraphy	
	Dorsal Spine, lateral	1,800			65	1	105	Laminagraphy	
22	Dorsal Spine		7	60					Martin
32	Dorsal Spine, anteroposterior	4,700	8	11	62	0	200		Stanford and Vance
	Dorsal Spine, lateral	10,500	13	2.1	68	0	200		
2	Dorsal Spine, anteroposterior	480	1	1.3	75	3	80		Ardran and Crooks
8	Lumbar Spine, anteroposterior	660	0	225	72		100		Billings *et al.*
	Lumbar Spine, anteroposterior	250	0	95	120		13	High voltage	
	Lumbar Spine, lateral	800	0	80 lower 480 upper	78		200		
	Lumbar Spine, lateral	500	0	100 lower 500 upper	120		70	High voltage	
25	Lumbar Spine	Center of Abdomen		5,000				Three films	Moore
29	Lumbar Spine	Center of Abdomen		8,000				Five films	Ritter *et al.*
22	Lumbar Spine, anteroposterior		4–9.5	20–160					Martin
	Lumbar Spine, anteroposterior			7.6–13				High voltage	
	Lumbar Spine, lateral		20–36	60–300					
	Lumbar Spine, lateral			20				High voltage	
32	Lumbar Spine, anteroposterior	5,200	24	227	68	0	200		Stanford and Vance
	Lumbar Spine, anteroposterior	1,000	6	40	120	0	20	High voltage	
	Lumbar Spine, lateral	12,400	26.6	86	72	0	500		
	Lumbar Spine, lateral	4,800	7	16	120	0	60	High voltage	
2	Lumbar Spine, anteroposterior	480	0.5	95	75	3	80		Ardran and Crooks
	Lumbar Spine, lateral	2,000	2.25	270	85	3	300		
8	Lumbar Sacral, lateral	2,050	0	60 upper 0 lower	120		100		Billings *et al.*
32	Lumbar Sacral, anteroposterior	3,900	22	220	80	0	300		Stanford and Vance
	Lumbar Sacral, anteroposterior	1,000			120	0		High voltage	
	Lumbar Sacral, lateral	17,000			80				
	Lumbar Sacral, lateral	8,800	15	800	120	0	350	High voltage	
22	Lumbar Sacral		30	250				Per film	Martin
2	Lumbar Sacral, lateral	3,000	2	350	90	3	400		Ardran and Crooks

be discussed only briefly here. Though most reports indicate a skin dose of several roentgens per film, the use of filtration, long cone, and fast film reduces the skin dose to less than 0.1 r per film. With the short cone technique, an ovary dose of 0.06 mr per film has been reported[32] and 0.34 mr for the testes. The male dose can be reduced to essentially zero with shielding. Gonadal doses are highly dependent upon patient posture and tube angulation.

Comments on Tables. A few conclusions emerge from a study of these tables. Not all techniques, particularly fluoroscopy, have been adequately studied. Wide variations exist in the reported values of skin and gonadal dose. Though some of this may be due to different measurement procedures, most of it is probably a reflection of the real and large differences which exist among radiologists, depending on the filtration, field size, angulation, use of protective shields, kilovoltage employed, film and screen speeds, etc. Attention to all of these factors produces important decreases in dose.

As has been emphasized by others,[3] these variations are real. This makes it meaningless to specify a single value for each type of examination as having general applicability.

MEASUREMENT OF BONE, SKIN, AND GONADAL DOSE FOR CHEST EXPOSURES

Measurements are reported here which have been made with the phantom described above for three procedures which yield posteroanterior roentgenograms for the chest. The purpose of these measurements was to obtain the relationship between the bone marrow dose and skin dose for a common examination in which much of the active bone marrow is exposed. The three procedures were examined as they were being carried out in actual practice and the absolute values of the measured doses definitely do not represent the minimum obtainable. Nor are the three procedures comparable since they were used for different roentgenographic criteria of the necessary density for a diagnostically suitable film; different darkrooms were involved; and other factors such as the film, developing time, and developer were different. The three procedures were: roentgenography with conventional 14×17 inch. film, photofluorography with 70 mm. film and f 1.5 lens, and photofluorography with mirror optics.

In this survey Landsverk "finger" ionization chambers (L-81) were employed because our own model described above was still in the developmental stage. These chambers had the least energy dependence in the diagnostic region of those commercial chambers available to us. They were calibrated individually and had response variations of about 35 per cent from 0.5 mm. Al half value layer to 3.0 mm. Al half value layer.

It was found, however, that the charging voltage of the Landsverk electrometer (model L-60) was not adequate for the chambers with the high dose rates encountered in diagnostic work. A Baldwin-Farmer electrometer was fitted with adapters to accommodate the Landsverk chambers, so that they were charged at 250 volts which allowed their use at high dose rates. The ionization chambers were used within the phantom at three positions in the spine (C7, T6, and L1), two in the scrotum, two over the ovaries, and one each on the entrance and exit skin field surfaces.

The techniques employed were based on the size and shape of the phantom, which represents a medium sized young adult. A roentgenographic unit was set up exactly in the same manner as for a routine upright posteroanterior roentgenogram of the chest. The physical factors were: 85 kv., 15 mas., and 72 inches target film distance. The cone used was the small (13.5 cm. diameter) circular one supplied by the manufacturer for chest work. With this cone there was an 83 cm. diameter radiation field at the film. The film was Eastman Kodak Blue Brand with two Patterson Parspeed screens. No grid was used. There

was an added filter of 1.5 mm. Al on this unit and the absorption curve indicated a half value layer of 2.7 mm. Al. All measurements were made with the phantom duplicating the patient position at a wall mounted film holder.

One of the photofluorographic units employed had an f 1.5 camera lens, while the other had mirror optics. Both were phototimed and had a 40 inch target film distance and grids.

The first unit was operated at 90 kv. with an added filter of 2.5 mm. Al, corresponding to a measured 3.2 mm. Al half value layer. The field size at the screen was 53×49 cm. for the vertical and horizontal dimensions, respectively. The film used was Ansco photofluorographic green sensitive film. The unit was operated so as to produce less dense images in the film than the second unit.

The second unit was operated at 93 kv. with an added filter of 1.5 mm. Al which produced a measured half value layer of 2.6 mm. Al. The film employed was Eastman Kodak Photoflure green sensitive film. The radiation field at the screen was 46×46 cm.

It is emphasized that these units were not operated in a comparable technical manner, or for the same film density. However, they were all employed in a responsible manner to produce films of adequate diagnostic quality for the various radiologists concerned.

All measurements made on the units were timed by counting the number of pulses of roentgen rays as indicated by the shadow of a spinning top. This was necessary to check the reproducibility of the phantom exposures, to check the similarity of exposure for a group of patients and the phantom, and to time the exposures made in the determination of the absorption curves. The reported doses are averages with the standard deviations indicated for the entrance skin doses. The variation in the smaller doses is greater. These measurements are to be repeated when several of the conducting polystyrene chambers are available.

Skin Dose. Study of Table XII indicates that the doses for the exit skin and various spinal positions had the same relation percentage-wise to the entrance (posterior) skin dose for all three units. In the case of

TABLE XII

AVERAGE RADIATION DOSES (mr) FOR POSTEROANTERIOR CHEST ROENTGENOGRAM*

Position	Roentgenographic Large Film Unit		Photofluorographic Unit with f 1.5 Lens		Photofluorographic Unit with Mirror Optics
	mr/exposure	Per Cent	mr/exposure	Per Cent	Per Cent
Skin	59±9	100	520±22	100	100
Exit	4	6	41	8	8
Spine					
C 7	16	28	144	28	23
T 6	26	44	223	43	37
L 1	25	42	169	33	28
Testes	1	2	2	0.4	0.8
Ovaries	3	5	1	0.2	0.4
kv.		85		90	93
mas.		15		30	
Target Film Distance		72 in.		40 in.	40 in.
Field Size at Screen or Film		83 cm.dia.		53 cm.×49 cm.	46 cm.×46 cm.
Added Filter		1.5 mm.Al		2.4 mm.Al	1.5 mm.Al
Half Value Layer		2.7 mm.Al		3.2 mm.Al	2.6 mm.Al
Film	Eastman Kodak Blue Brand		Ansco photofluorographic green sensitive		
Screen	Patterson Parspeed		Radelin PFG2		

* These measurements were made to obtain the relationship of bone marrow and gonadal dose to skin dose for three chest procedures. The absolute values of these three procedures are not strictly comparable because they were carried out under different operating conditions. For this reason only the percentages and not the absolute values are included for the photofluorographic unit with mirror optics.

the large film roentgenographic unit, although the smallest cone supplied by its manufacturer was employed, the ovaries and the pelvis were in the useful beam. The ovarian dose percentage of skin dose was appreciably higher for this unit than for the two photofluorographic units.

The absolute doses for bone marrow and skin were about 10 times higher for the first photofluorographic unit and also higher for the photofluorographic unit with mirror optics than for the large film roentgenographic unit. Since the two photofluorographic units were not operated under the same conditions, the absolute values for them are not comparable, and only the percentages are given in Table XII for the second photofluorographic unit.

Bone Dose. The bone marrow doses were measured with chambers inside the bone and should reflect the attenuation of the primary roentgen rays by the bone itself. Since some of the marrow is contained in small cavities, there is some enhancement of the marrow dose adjacent to bone due to the relatively increased secondary electron production in bone. This effect probably does not exceed 10 per cent and has been neglected here.

In the case of the large film roentgenographic unit the pelvis was in the useful beam. The average bone marrow doses are estimated as follows: spinal column, 22 mr; ribs, clavicles, scapulae, 14 mr; sternum, 7 mr; and pelvic bone, 10 mr. An average active marrow dose can be estimated if the percentage of total active marrow in each of these bones is known. This information apparently does not exist. Rough estimates by some hematologists result in the following percentages for the regions in the order listed above: 40 per cent, 20 per cent, 10 per cent and 30 per cent, respectively. It is emphasized that these percentages are speculative and unsupported by measurement at present. Use of these percentages results in an average dose of 15 mr in the normally active marrow. For an individual with 1,500 gm. of active marrow, this corresponds to an integral dose of 22.5 gm. r per large chest film. If the field size were as restricted as on the photofluorographic units, none of the pelvis and about 70 per cent of the spinal column would have been in the useful beam. This would have reduced the average dose in the active marrow to about 9 mr, and the integral dose for 1,500 gm. of active marrow to about 13.5 gm. r.

In the case of the first photofluorographic unit, 70 per cent of the spinal column and none of the pelvis were in the useful beam. On the basis of the data in Table XII the bone marrow doses are estimated as: irradiated spinal column, 175 mr; ribs, etc., 125 mr; and sternum, 80 mr. With a small allowance for the portion of the spine and pelvis outside the useful beam, the average dose over the active marrow is 104 mr. Again, for an individual with 1,500 gm. of active marrow this represents an integral marrow dose of 156 gm. r per exposure. A

TABLE XIII

ACTIVE BONE MARROW DOSE FOR POSTEROANTERIOR CHEST ROENTGENOGRAM*

Procedure	Average Active Bone Marrow Dose per mas. mr	Integral Dose for 1,500 gm. Active Marrow per mas. gm.-r
Roentgenography (72 in.)	1.0 (large field)†	1.5†
	0.6 (restricted field)‡	0.9‡
Photofluorography (40 in.)	3.5	5.2

* Technical factors as given on Table XII and in text.
† Field given by small cone which includes pelvis.
‡ Field similar to that of photofluorographic unit.

photofluorographic unit with mirror optics with similar technical factors would presumably produce an integral dose of about 50 gm. r per exposure, still about 4 times that produced with the roentgenographic unit with a limited field.

These results are summarized in Table XIII per milliampere-second to render them independent of the various film and darkroom factors. Assuming that modifications of film and darkroom techniques would permit reduction of the roentgenographic exposure to 4 mas. and that a reduction of the exposure of the photofluorographic unit with mirror optics to 10 mas. is possible, the integral doses (per film) would then be about 3 gm. r and 52 gm. r, respectively. On this basis, four photofluorograms would be required before the patient's active bone marrow received as much integral dose as received annually due to natural background (200 gm.-rem per year). These integral doses are several orders of magnitudes less than those delivered therapeutically[10] for which there is some evidence of bone marrow damage. Other diagnostic and therapeutic techniques (including radioactive isotope use) are being examined with this apparatus to determine their active bone marrow doses.

Gonadal Doses. (*1*) *Shielding of Gonads.* In Table XIV are data obtained with no shield, with a 2-ply Archer glass apron wrapped around the pelvis, and with a lead rubber apron (0.5 mm. lead equivalent) surrounding the pelvis. The Archer glass apron was supplied by Dr. N. Finby, New York Hospital, who designed it. In the case of the large film roentgenographic unit for which the ovaries were in the useful beam, a reduction of about two times was obtained with the lead glass girdle, and a reduction of five times with the lead rubber apron girdle. With the photofluorographic unit the field size was more limited and the reductions in dose are somewhat less, but still appreciable. The field size should be checked on all units, and the wearing of a girdle appears to be of demonstrable value.

(*2*) *Factors in Estimation of Total Population Gonadal Dose.* As emphasized above, the authors do not believe that a given procedure can be represented by a single gonadal dose value which will have general application because of the pronounced variation among different departments. This variation is probably increased among the diagnostic practices of non-radiologists. However, if one assumes that a range of valid gonadal dose values can be assigned to a given procedure for patients of a given age and sex group and for different categories of practitioners, certain additional statistics are necessary to obtain an approximate estimate of the total gonadal dose.

(*a*) The distribution of patients undergoing each type of examination by age and sex is necessary. This information exists in a convenient form for a few hospitals and health plan groups, but this information is fragmentary and of questionable general applicability.

The absolute number of patients as well as their relative distribution must also be

TABLE XIV

USE OF SHIELDS TO PROTECT GONADS

	Large Film Roentgenographic Unit			Photofluorographic Unit		
Position	1 Per Cent*	2 Per Cent†	3 Per Cent‡	1 Per Cent*	2 Per Cent†	3 Per Cent‡
Skin	100	100	100	100	100	100
Testes	2	0.8	0.4	0.8	0.3	0.3
Ovaries	5	2.8	1.0	0.4	0.3	0.1

* No protective shield.
† Two-ply Archer cloth apron surrounding pelvis.
‡ Lead rubber apron surrounding pelvis.

known. The total number of examinations can be estimated independently from data on the activities of each of the professional categories using diagnostic roentgen rays, from statistics of the film companies on medical film consumption, from film consumption statistics of the Department of Commerce, from Public Health Service data on film consumption, and from United Hospital Fund film data. Estimates on these various bases are in reasonable agreement and indicate that there are approximately 38 million roentgenographic examinations annually of which about 32 million are made by radiologists or in hospitals, that there are about 13 million fluoroscopic examinations per year of which slightly less than half are performed by radiologists or in hospitals, and that there are about 3 million photofluorographic examinations per year in hospitals. The mass chest survey is not included in this tabulation.

(*b*) The number of films per examination should be known for each type of examination and as a function of age, diagnosis and sex.

(*c*) The amount and precise type of fluoroscopy must also be known for each type of examination and as a function of diagnosis, age, and sex.

These two quantities (*a* and *b*) are known only partially for some hospitals and essentially not at all for non-radiologists.

The age of thirty has been found to the approximate age of one generation in the United States. If the distribution of type of examination by age were constant or symmetric, the statistics for patients either above or below this age could be employed. In the absence of valid data on the distribution of patients by type of examination, age, and sex, this assumption is necessary and increases the uncertainty of the resulting estimate. There is some evidence that this assumption may not be too unsatisfactory. In a comparison of the two methods[27] (all those below thirty years of age versus frequency distribution by age), the resultant average gonadal dose agreed to within 7 per cent.

(*d*) In order to obtain the *genetically significant* dose, knowledge of the total gonadal dose is inadequate. This is because the reproductive expectation of diagnostic patients may be different from that of the general population. This consideration requires knowledge of the frequency of births to diagnostic patients following exposure as compared with the general population. Such data would be difficult to obtain.

If the above statistics were all known, the resulting estimate would still be only approximate. A more significant estimate can be obtained by selecting a representative sample of radiation practitioners and making a comprehensive study of the radiation experience of their patients. Such selected sampling methods have been highly developed for other determinations and should be applicable to this problem.

DISCUSSION

Although reference to the various studies of diagnostic exposures tabulated here provides an idea of the magnitude to be expected for a given procedure, we believe that the difference in reported doses reflects real variations. As a result of the large number of parameters which affect the magnitude of the exposure per film, appreciable differences will probably exist for given procedures among the best departments.

Subject always to the requirement of a roentgen film adequate for diagnosis, the following factors can result in appreciable reductions of patient exposure: use of an adjustable diaphragm to obtain the smallest field size necessary, use of heavy filtration and/or high voltage, use of scrotum shields or pelvic girdles, use of fast film and optimum developing chemicals and temperatures, and the use of image intensification where feasible.

Although much publicity has been directed towards gonadal exposure, there are other body components such as the marrow active in blood formation the exposure of which should be evaluated for both diagnostic and therapeutic techniques.

SUMMARY

1. Factors which are important in the measurement of radiation doses associated with diagnostic procedures have been discussed. Wavelength dependence and directional response properties of a chamber developed at Memorial Center, New York, have been described together with a phantom in which tissue, bone, lung and cavities have been simulated.

2. The gonadal and bone marrow dose produced by natural background radiation has been discussed with identification and some descriptions of the various sources.

3. The skin and gonadal doses as reported in the literature have been tabulated for the following procedures: examinations of the pelvis, pelvimetry, intravenous pyelography, salpingography, examinations of the stomach and upper and lower gastrointestinal tract, examinations of the abdomen including obstetrical examination, cholecystography, examination of the chest, examination of the cervical spine, dorsal spine, lumbar spine, and lumbosacral joint. Details of these studies have been commented on. The range of values has been emphasized, together with those factors which substantially reduced radiation exposure.

4. Preliminary measurements are reported with the use of a special phantom for three different chest examination techniques. The primary purpose of these measurements was to determine the bone marrow and gonadal doses relative to skin and exposure dose. The integral bone marrow dose was estimated from these measurements and compared with that due to natural background.

5. The results of the above measurements emphasize the importance of associated technical factors; the number of parameters in diagnostic technique is sufficiently large that measurements with a particular unit do not have general applicability unless all operating conditions are identical.

6. The advantage in reduced radiation exposure with the use of limited fields (facilitated by adjustable collimators), high filtration or voltage, pelvic shields, and fast film are emphasized.

7. The various statistical quantities which are involved in the translation of dose measurements into estimates of total population gonadal exposure are identified and some of the present data limitations are defined.

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PRACTICAL SUGGESTIONS FOR REDUCING RADIATION EXPOSURE IN DIAGNOSTIC EXAMINATIONS*

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IN THE previous articles very good reviews were given of the reasons why it is necessary to reduce radiation exposure. The problem then confronting us is to accomplish a reduction of unnecessary radiation exposure to all persons to the barest minimum commensurate with achieving the necessary clinical diagnosis. In this process we have to consider protection for the physician, together with the protection of his technicians or nurses; to minimize the dose to the patient and to shield the public from radiation exposure over which it has no control.

The details of this report should be well known to practically every radiologist; a few new facets may be added but, by and large, most of the good advice necessary to reduce diagnostic dose is adequately covered in the literature.

Specifically, reference should be made to two primary sources of information. The first is Handbook 60 on X-ray protection prepared by the NCRP in this country. The other is the Recommendations of the International Commission on Radiological Protection.

Sections 6 through 10 of Handbook 60 comprise about 10 pages and if applied rigorously will aid considerably in reducing exposure of the patient and the physician to the lowest practical level.

If one follows the recommendations contained in the two sources just mentioned, he will be doing nearly all that is possible with our present-day modern X-ray equipment.

INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

D. VIII. 1. General Rules. By X-ray protection of the patient it is meant that the radiation exposure of the patient should be reduced as much as is compatible with successful diagnostic investigation or therapeutic treatment.

On the whole our new equipment is being manufactured in accordance with the recommended requirements, and it is not anticipated that any fundamental changes in this equipment will result in substantial improvements with regard to radiation shielding. One cannot help but advise at this point that all obsolete equipment should be discarded. It is regrettable that there is in use in this country too much X-ray equipment dating back many years which uses such shields as glass bowls without adequate diaphragm, filters or cones.

In discussing the available up-to-date equipment, let us start with the radiation at its source, namely, the roentgen-ray tube.

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Definition

Diagnostic-type protective tube housing. One that reduces the leakage radiation to at most 0.10 r/hr at a distance of 1 m from the tube target when the tube is operating at its maximum continuous rated current for the maximum rated voltage.

The present-day tube housing is one that reduces the leakage radiation to at most 0.10 r per hour at a distance of 1 meter from the tube target when the tube is operating at its maximum continuous rated current for the maximum rated voltage. Any tube housing providing less protection than this should be discarded. Consideration is being given to the establishment of a still lower value.

The use of proper cones will go far toward reducing stray radiation which may reach both patient and operator.

* Presented at the Fifty-eighth Annual Meeting of the American Roentgen Ray Society, Washington, D. C., October 1–4, 1957.
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6.1.c. The cone shall extend from the tube housing to a position as near the panel as possible. Its walls shall provide the same degree of protection as the tube housing, but may not require so great a thickness because of the obliquity of the rays.

e. The total filter—permanently in the useful beam—shall be equal to at least 2½ mm. of aluminum.

Section 6.1.c of Handbook 60 says that "the cone shall extend from the tube housing to a position as near the panel as possible. Its walls shall provide the same degree of protection as the tube housing. . . . " In this same connection the ICRP recommendations state that the cone or other restricting device should be detachable for occasional contact roentgenograms, but its construction should be such that the absence of this cone or other restricting device is quite evident.

INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

D. VI. 5. (b) (ii). The cone or other restricting device should be detachable for occasional contact radiographs, but its construction should be such that, in this case, the absence of the cone or other restricting device is quite evident. It should be noted that damage has occurred to workers and patients from contact radiography.

In this connection it should be pointed out that there is frequently a tendency to remove the cone for certain types of examinations and then either forget to replace it or to deliberately leave it off because of the small nuisance involved.

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6. Medical Fluoroscopic X-Ray Installations.

6.1 Equipment

a. The tube housing shall be a diagnostic type.

b. The useful beam shall be limited by a cone and an adjustable diaphragm that, when open to its fullest extent, leaves a margin of at least one-quarter inch of unilluminated fluorescent screen regardless of screen position during use.

The proper use of diaphragms is important in dose reduction, and a requirement of long-standing is that an adjustable diaphragm, together with the cone, should be such that when open to its fullest extent, there is a margin of at least ¼ inch of unilluminated fluorescent screen regardless of the screen position during use.

In connection with diaphragms there are some areas where equipment and techniques may possibly be further improved. In all diagnostic situations the beam that strikes the patient should have a shape and cross section no larger than is essential for the particular examination. This is particularly important for fluoroscopy. Some authorities recommend the use of adjustable diaphragms where each dimension can be adjusted independently, thus giving fields of any desired dimension. In fluoroscopy there may be some virtue in the use of spring-back or dead-man shutters. With this arrangement the mechanism would require the operator's hand at the controls in order to hold the shutters open at whatever size desired. In addition to keeping the shutter closed when not actually needed, it would also induce the doctor to use smaller fields because of the additional procedure in opening them to full size.

In radiography the exact positioning of a field can be relatively difficult because one does not have the aid of a fluorescent screen with which to make adjustments. To overcome this, field edge illuminators might serve usefully. Through the additional employment of an adjustable diaphragm, it would be possible to use minimum field sizes.

Diaphragming and coning are badly neglected in the dental field.

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8. Dental Radiographic Installations.

8.1 Equipment.

b. Diaphragms or cones shall be used for collimating the useful beam and shall provide the same degree of protection as the tube housing.

e. The exposure control switch shall be of the "dead-man" type and shall be provided

with a cord sufficiently long that the operator can stand at least 5 feet from the patient for all exposures and well away from the useful beam.

Because the dentist occasionally wishes to take a large-field roentgenogram, he may remove the limiting diaphragm—if one is present initially. Once removed the chances are that it would not be replaced. Casual questioning of a considerable number of dentists indicates that for the most part they have no knowledge of the diaphragm conditions in their roentgen-ray tube housing.

Still dealing with the radiation source, it is, of course, essential to reduce fluoroscoping time as much as possible.

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6.1.g. The target-to-table panel distance should not be less than 18 in. and shall not be less than 12 in.
6.1.i. A manually reset cumulative timing-device should be used which will either indicate elapsed time or turn off the apparatus when the total exposure exceeds a certain previously determined limit given in one or in a series of exposures. If the device indicates elapsed time, it should have a maximum range of 5 min.

Paragraph 6.1.i of Handbook 60, says that a manually reset cumulative timing device should be used, which will either indicate elapsed time, or turn off the apparatus when the exposure exceeds a previously determined limit given in one or in a series of exposures. If the device indicates a lapsed time, it should have a maximum lapse time of five minutes. The use of such a timing device will by its existence have a salutory effect on fluoroscopic procedures. By setting the time limit short enough, it can remind the physician of the need for speed in operation.

Attention is directed in the ICRP report to the reduction in patient dose which has brought about the use of high voltages and high filtrations. This has also been demonstrated by work done a few years ago by Trout. Curves in the ICRP report give some idea of how the ratio of exit dose versus entrance dose changes as a function of voltage and filtration. In connection with this, the ICRP report states that in order to reduce both the skin dose to the patient, and the scattered radiation reaching the operator, the following recommendations should be observed: (1) Fast film should be used. (2) Higher potentials may be frequently used without detriment to the diagnostic quality of the film. (3) Added filtration of the primary beam up to 3 mm. of aluminum should be used.

INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

D. VI. 1. (e) The fixed total filter equivalent value should be at least 2 mm. aluminum, and should be based on the value obtained at the highest voltage of the X-ray apparatus.

Actually the ICRP recommends a minimum of 2 mm. of aluminum of filtration for roentgenographic and fluoroscopic work. The NCRP recommends a minimum of 2½ mm. of aluminum.

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6.1.1 An apron of ¼ mm. lead equivalent hanging between the patient and the fluoroscopist in horizontal fluoroscopy is recommended but shall not substitute for the wearing of a protective apron.
6.3 Operation of apparatus.
a. The fluoroscopic equipment shall be operated only by a properly trained person authorized by the radiologist in charge to conduct fluoroscopic examinations.

Protection of the physician and the operator is one of the less difficult tasks facing us. Flexible aprons attached to the apparatus can be used to effectively minimize radiation scatter from the patient particularly in horizontal fluoroscopy.

Should one mention the wearing of a protective apron or robes? Too often they are omitted. Should one mention lead rubber gloves?

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6.3.d. Unless measurements indicate that

they are not needed, protective aprons shall be worn by the physician, nurse, technician, and all other persons within the fluoroscopic room who are frequently or habitually exposed to radiation hazard.

e. Unless measurements indicate that they are not needed, protective gloves shall be worn by the fluoroscopist during every examination.

The lead gloves can be used in most situations except where delicate palpation is occasionally called for. Gloves are available and should be used. Despite imperfections, a cracked glove or apron is better than none at all.

The inverse square law has real charm when it comes to radiation protection. Operations should be planned in such a way as to keep operating personnel as far as possible from the source and from the patient.

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6.3.f. The hand of the fluoroscopist, either with or without gloves, shall never be placed in the useful beam unless the beam is attenuated by the patient.

7.1 Equipment.

7.1.c. The total filter—permanently in the useful beam—shall be equal to at least 2½ mm. of aluminum.

Visiting persons should not be allowed in the fluoroscopic room during examination of the patient whenever possible. It is all too frequent that other physicians will stand around during the fluoroscopy of a patient when their services are not really needed.

In considering the problem of the direct protection of the patient, one should observe all of the recommendations in the national and international reports.

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7.3 Operation of Apparatus.

c. No person shall be regularly employed to hold patients during exposure nor shall anyone from the department of radiology ever be permitted to perform such service.

d. Only persons required for the radiographic procedure shall be in the radiographic room during exposure.

e. The radiographic field shall not be larger than clinically necessary.

The proper field alignment is very important. Where it is impossible to perform the necessary examination without directly exposing the gonads, they should be shielded. This has been stressed for many years and to some extent may be practiced. A variety of shields have been proposed for the scrotum. Apparently one of the major problems here is a matter of delicacy in applying the shield for routine examination. Nevertheless such shields can definitely serve to reduce the gonadal dose in many situations. Shielding of the ovaries is more difficult and can never be done completely. About the most that can be hoped for is shielding them from the direct beam.

Various proposals have been made for local shielding, for example, the lower part of the body, while examining the chest. This can be done but it has its problems. If this type of shielding is to be used, it should be used against scattered as well as direct radiation. Probably more effective dose reduction can be accomplished by adequate diaphragming and positioning. Is it necessary to caution about the use of minimum size fields for the chest examination of infants?

A frequent but easily avoidable source of overexposure to the gonads is in roentgenography of the head, arms, and hands. Under such situations it is not uncommon for the patient to sit down with his hand or head on a cassette on top of a table and then have a direct beam either hit or narrowly miss the gonads.

The protection of outsiders is accomplished by proper room shielding, tube housing and orientation of the beam. All the necessary information is contained in Handbook 60.

A few more things may be mentioned briefly.

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6.3 Operation of Apparatus.

b. The eyes of the fluoroscopist should be well dark-adapted before he uses the fluoroscope.

c. Fluroscopic work shall be performed in the minimum time possible using the lowest dose rate and smallest aperture consistent with clinical requirements. If a high-low switch is available, as suggested in section 6.1.h, then the low dose rate shall be used to locate the area of interest and the high dose rate only momentarily to explore the area of interest.

It is generally known that the eyes should always be dark adapted for about twenty minutes. Most radiologists observe this requirement. Most general practitioners do not. To overcome the handicap of the lack of dark adaptation, the examination may necessarily be extended with consequent overexposure of the patient and the physician.

The film processing is usually done in the average radiological department on a scientific basis. The exposure is adjusted to fit the film processing technique. Again the general practitioner will have difficulty and more often than not he will overexpose the film, and then under develop it, watching until he thinks the image is about right. This not only overexposes the patient but frequently results in a film of poor quality.

Great caution is necessary when using the photofluorographic units. These units most decidedly have their place in our medical practice, but the patient's dose from such a unit is likely to be ten times greater than the dose using the standard film technique. One of the main points to observe in the use of chest survey units is proper alignment of the beam. This is often handled haphazardly and the field is often unnecessarily large. The gonads can be shielded relatively effectively by simply placing a lead rubber apron of adjustable height between the patient and the tube. Regardless of the tube position, the apron would be adjusted to a standard height, relative to some fiducial position on the patient.

Through cooperation between the radiologist and the manufacturer, the development of improved safe equipment has been possible. An outstanding example of this is the image intensifier.

INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

Recommendations regarding the following items are under consideration by the ICRP

a) The provision of specially designed protective devices for the gonads of patients.
b) Additional recommendations regarding minimum film-focus distances.
c) Increasing and protective requirements for diagnostic and therapeutic tube housings.
d) Improvements in beam collimation.
e) The provision of permanent filters of at least 2 mm. Al equivalent on all diagnostic X-ray tubes.
f) The advantages of using high-voltage techniques for diagnostic work.
g) The provision of exposure counters on all diagnostic equipment.
h) The use of image intensifiers to reduce the dose to the patient, and consequently to the operator, rather than as a means of permitting more extensive and prolonged fluoroscopy than hitherto.

The image intensifier was conceived, in the main, as a device for enabling a diagnostic examination to be made with less exposure to the patient. Using the image intensifier, it is possible to work with relatively little or no dark adaptation and in relatively bright rooms. Unfortunately, these very things undo some of its main benefits. If image intensifiers are to be used they should be used in darkened rooms and with proper dark adaptation of the eyes.

In closing one may unhesitatingly state that it is possible, with a little thought and understanding, to very appreciably reduce not only the gonadal dose of our population as a whole but the dose to the remainder of the body where it can do no good and may do harm.

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PAST AND PRESENT RADIATION EXPOSURE TO RADIOLOGISTS FROM THE POINT OF VIEW OF LIFE EXPECTANCY*

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THE life span of radiologists has received considerable attention since the publication by the National Academy of Science of Shields Warren's statistical studies.[7,8] Warren reported that the average age at death was 60.5 years for radiologists compared with 65.7 years for other physicians with no known occupational radiation exposure. His results, however, were based on the longevity of physicians who, in general, practiced radiology when the hazards were considerably greater than they are at present. The same is true of the results of March's[6] earlier studies which indicated a significantly higher incidence of leukemia among radiologists than other physicians.

There is no direct method of relating life span, or incidence of leukemia, to past occupational exposure. Area surveys and personnel monitoring, unfortunately, have been the exception rather than the rule until recent years. Warren gives a wide range for the accumulated exposure dose, from a very slight value to about 1,000 r. Lewis[5] has suggested that the average exposure rate for all radiologists has not exceeded the 1931 maximum permissible limit of 0.2 r/day. There is reason to believe, however, that earlier common disregard of systemic injuries and the lack of personnel monitoring have resulted in exposures significantly in excess of the then prevailing "tolerance" doses. On the other hand, present personnel monitoring indicates that today the average exposure to any major part of the radiologist's body is considerably below the present maximum permissible average value of 100 mr/week.

It is of interest, therefore, to compare the radiation levels of old type roentgen installations* with those of modern facilities. In this way it is possible to get an approximation of the average dose received by radiologists practicing some twenty-five years ago. It is realized that the dose is affected also by other conditions, such as working habits and amount of fluoroscopy. These factors will be discussed later.

FLUOROSCOPY

Of the various roentgen procedures, fluoroscopy, no doubt, presents the greatest hazard to the radiologist. This was particularly true when nonprotective fluoroscopes were used. This is illustrated in Figure 1 which shows the results of radiation measurements made on an obsolete vertical fluoroscope set up in the laboratory for this purpose, and of those made on modern equipment. It will be seen that the radiation levels an old type fluoroscopes were 3 to 9 times greater than those measured on modern apparatus. In addition, the present more general use of protective aprons has reduced further the average dose to the greater part of the fluoroscopist's body by a factor of about 25. One of the largest clinics in the country did not use protective gloves nor aprons between 1918 and 1934.[4] After this period the fluoroscopists used gloves and aprons made of a special fabric with a lead equivalent of only 0.1 mm. Our results show that the exposure formerly received by fluoroscopists not using protective aprons was about 75 times greater than that obtained with modern equipment and present safeguards. This is in line with the findings reported by Cowie and Scheele[2] in

* Old type installations refer in this report to those with nonprotective equipment as was commonly used some twenty-five years ago.

* From the Physics Laboratory, Francis Delafield Hospital, New York, New York. Presented at the Fifty-eighth Annual Meeting of the American Roentgen Ray Society, Washington, D. C., October 1–4, 1957.

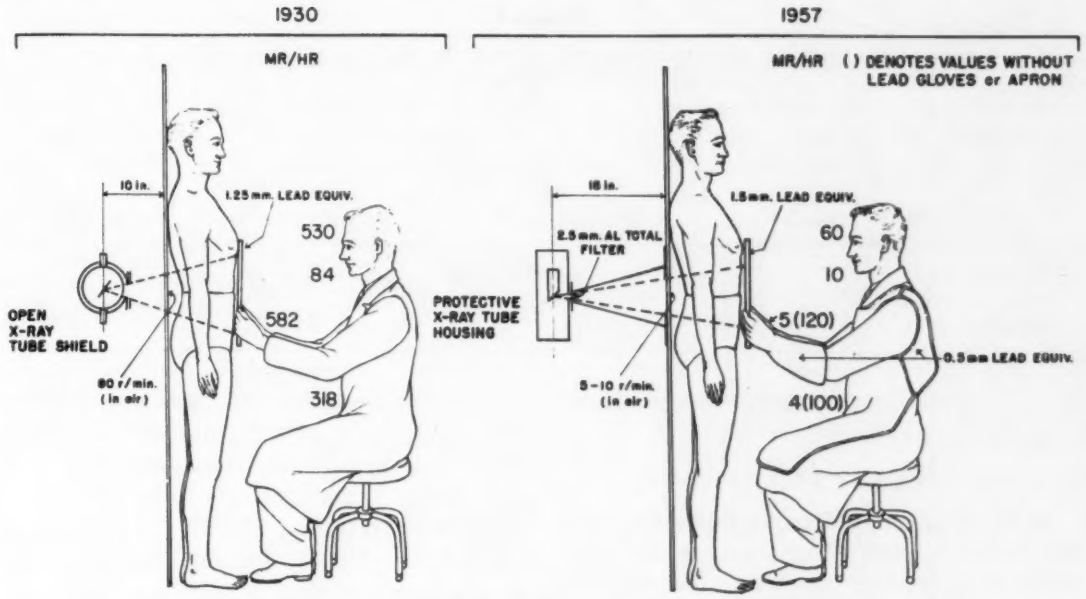

Fig. 1. Comparison of stray radiation from vertical fluoroscopes.

1941. Their surveys of 45 hospitals indicated that in more than half of these at least one member of the staff received more than 100 mr/day and in an extreme case 2,000 mr/day; the present average is about 4 mr/day.

ROENTGENOGRAPHY

The present use of protective tube housings and more extensive room shielding has greatly reduced the stray radiation of roentgenographic installations. With the open bowl type tube holder, no shielding was provided along the axis of the tube. In addition to the useful beam pointing down, there was an almost equally intense horizontal beam directed at the walls of the room. Without wall shielding this resulted in significant stray radiation in adjacent rooms, of the order of 25 to 50 mr in one hour. If the radiologist's office were next to the diagnostic room, this condition may have contributed greatly to the dose he was getting. Present shielding of tube housing and walls usually reduces the radiation to much less than 2.5 mr in one hour.

THERAPY

Many of the deceased radiologists were roentgen therapists as well as diagnosticians; relatively few used radium. This study, therefore, is limited to roentgen installations.

Table I shows representative radiation levels of the old type therapy installations with open lead glass bowl tube holder. The machines in private offices were usually operated by radiologists rather than by technicians. As shown, the average exposure rate was about 50 mr/hr., or approximately 25 times the present levels.

The high radiation levels were due not only to the use of open tube holders but also to the lack of adequate structural protection. At that time the lead shielding of the walls generally did not extend above 6 or 7 feet and, consequently, there was excessive scatter over the lead barriers.

Even with the lead drum type tube enclosures, which were also used at that time, inadequate room shielding frequently resulted in excessive stray radiation outside the treatment room. This is shown in Table II. In addition to the surveys summarized in Tables I and II, measurements were made also on an almost equal number of installations where stray radiation was of the order of 5 mr/hr. Earlier surveys reported by Fricke and Beasley[3] in 1923 for a num-

TABLE I

RESULTS OF RADIATION SURVEYS MADE FROM 1933–1937 OF 200 KV. NONPROTECTIVE THERAPY INSTALLATIONS[1]

Installation	Private Offices					Hospitals	
Location of Measurements	F mr/hr.	M mr/hr.	N mr/hr.	S mr/hr.	W mr/hr.	B mr/hr.	K mr/hr.
Control panel	96	57	10	46	46	9	10
Adjacent room	77	93	51	210	116	49	15
Corridor	293						

ber of therapy installations show a similar wide range in radiation levels.

PAST EXPOSURE TO RADIOLOGISTS

Most of the deceased radiologists have worked with both nonprotective and protective equipment. As a first approximation, it may be assumed that the average dose received by the radiologist was the mean for the two conditions. Most of the older radiologists who practiced prior to 1930, no doubt, have worked under conditions considerably worse than reported here. This is particularly true of those who did field fluoroscopy during World War I. On the other hand, the younger radiologists, who died recently, have used protective equipment only.

Table III gives an estimate of the average accumulated exposure to radiologists using nonprotective equipment for assumed hours of operation.

Too few radiation surveys were made in the past to establish any relationship between the life span of the individual radiologist and the radiation levels of his installation. In fact, most of the radiologists who were in charge of installations where the 1933–1937 surveys showed excessive stray radiation are not only alive today but still practicing radiology. However, all of them took steps to improve the protection, while others who had no surveys most likely continued to work under hazardous conditions for many years.

TABLE II

RESULTS OF RADIATION SURVEYS OF 200 KV. THERAPY INSTALLATIONS WITH LEAD DRUM TUBE HOLDER, BUT INADEQUATE ROOM SHIELDING[1]

Installation Location of Measurements	K mr/hr.	JH mr/hr.
Control panel	5	5
Adjacent rooms	54	710
Floor below		2,700

PRESENT RADIATION LEVELS

Today's increased attention to protection has resulted in significant reduction in the exposure to radiologists. Radiation surveys and personnel monitoring have shown up most of the hazardous situations. There still is room for improvement, particularly in fluoroscopy. It is hoped that the fluoroscope of the future will be designed to incorporate more effective secondary protection, eliminating the present cumbersome and incomplete shielding provided by the apron and gloves worn by the fluoroscopist. Such a change would conform with

TABLE III

ESTIMATED CUMULATED EXPOSURE TO RADIOLOGIST USING NONPROTECTIVE EQUIPMENT

	hr./da. of irradiation	r/da.	r/yr. (250 da.)
Fluoroscopy 300 mr/hr.	1	0.3	75
Roentgenography 25 mr in 1 hr.	2	0.05	12.5
Therapy 50 mr/hr.	1	0.05	12.5
Total	1	0.4	100

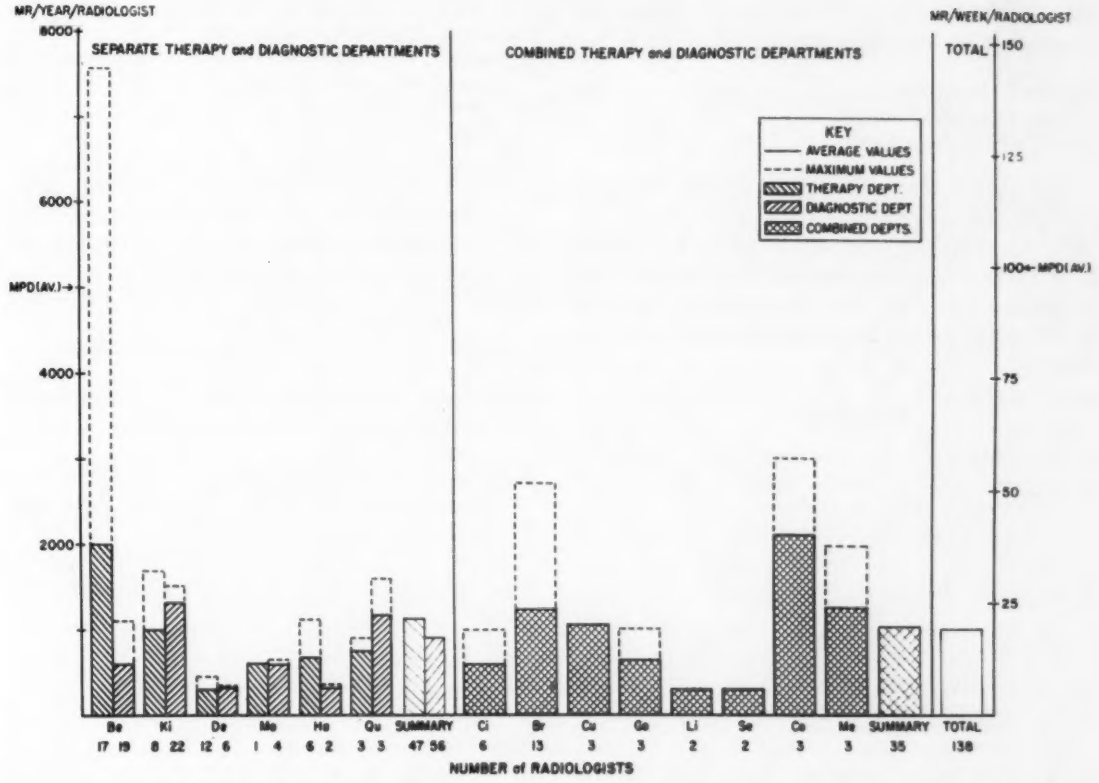

FIG. 2. Results of personnel monitoring of radiologists. Results include all doctors who worked six months or longer in the radiologic department; where the service was less than a year, yearly exposure has been extrapolated.

the basic principle of protection by placing the shielding where it belongs, that is, at the source of the radiation rather than around the person to be protected.

Figure 2 shows the results of film badge monitoring carried out in a group of New York hospitals. It will be seen that the average yearly cumulative dose received by the radiologist today using present standards of protection is only one fifth of the permissible value; the high maximum exposures were due mainly to the handling of radium. Personnel monitoring has proved of distinct value in reducing radiation hazards. It is very questionable, however, that past results can serve for future evaluation of radiation effects on man. For this purpose we need a more sensitive detector and a simple index of radiation quality. It is essential to know the energy of the rays in order to determine the absorbed dose in rads for the vital tissues which affect life expectancy. Another requirement is that the monitor is worn on the part of the body where irradiation is most likely to affect longevity.

SUMMARY

The results of this study indicate that the average accumulated exposure dose received by radiologists using nonprotective equipment was of the order of 100 r per year. With present standards of protection, the yearly dose is reduced to about 1 r.

The average life time dose of the radiologists studied by Warren may, for lack of more complete information, be assumed to be the mean for the two extremes, or about 2,000 r for forty years. If reduction in life span is proportional to the dose received, it may be inferred that radiologists using present safeguards do not need to fear any

significant future reduction in their life span due to irradiation.

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COMMON SENSE IN RADIATION PROTECTION APPLIED TO CLINICAL PRACTICE*

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"STRESS must be laid once more upon the importance of avoiding all unnecessary exposure to the rays. . . . The rays have an undoubted power of producing sterility in both sexes. . . . The danger to the patient is also a very important point that must never be lost sight of by the radiologist. . . . It is advisable to have some idea of the exposure we may give the patient during the course of an X-ray examination without causing him to suffer any ill effects. . . . " The above quotation sounds like an admonition of 1957 but in reality it is taken from Bythell and Barclay's[4] book on X-ray Diagnosis and Treatment published in 1912. Thirty years ago, in 1927, Kaye[9] reported that over 120 papers had been published on the physics of protection alone. In the same year Sir Humphry Rolleston[14] wrote, "It is important that the recommendations for protection should be based on the principles of absolute safety and so err, if they do at all, on the side of excess." (safety).

Anyone who studies the history of radiation protection knows that the matter of safety for the patient and for the physician has been considered ever since 1896. Many of those working with the rays, however, forgot about protection or did not learn of the dangers until too late. Hence, safety has not always been the rule.

The first interest in protection came from knowledge of the acute effects of the rays—first dermatitis and then epilation. Not knowing about chronic effects, a safe intensity of radiation based on a photographic method was postulated by Rollins[15] which we now estimate to have been about 10 r per day. During the next twenty odd years many more biologic effects of radiations were discovered both in animals and man, and some individuals wrote about protection, but the second general protest against the dangers of roentgen rays did not develop until the 1920's. At that time it was the development of aplastic anemias that brought matters to general attention and safety rules were developed and promulgated. By 1922 it was estimated that more than 100 of the pioneers in radiology had died from cancer caused by their occupation. The dangers from over-exposure were stated as being (a) visible injuries to the superficial tissues and (b) derangements of internal organs and changes in the blood.

Thus, gradually the idea of a dose such that it would produce no appreciable injury evolved. With the development of the roentgen as a reproducible physical measure of radiation, it was possible to state such a tolerance dose as 0.2 r per day in 1931. Since then there have been three reductions in what is now called the maximum permissible dose (Table 1). Many radiologists wonder why these reductions have occurred in view of the fact that no one is known to have been appreciably damaged who has stayed below the original 0.2 r per day. In 1936 the change to 0.1 r per day was made for two main reasons: (1) because more penetrating rays were in more general use than when the original level was established, and (2) because 0.1 r measured in air, as was customary in the United States, was about the same as 0.2 r measured on the skin in Great Britain and Europe.

The next change came in 1948 as a result of much animal experimentation and observation of many people exposed to radiation. It was found that very small amounts of radiation given over long periods caused

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Table I

OCCUPATIONAL TOLERANCE AND MAXIMUM PERMISSIBLE DOSES IN ROENTGENS

	Time Period			
	1931–36	1936–48	1948–56	1956
Per day	0.2 r	0.1 r	(0.05 r)	
Per 6 day week	1.2 r	0.6 r	0.3 r	0.3 r
Per 50 week year	60 r	30 r	15 r	5 r
Age 20–30	600 r	300 r	150 r	50 r
Per decade	600 r	300 r	150 r	50 r
Up to age 60	2,400 r	1,200 r	600 r	200 r

changes of various kinds and it was the consensus of the National Committee on Radiation Protection and of the International Commission that the factor of safety was not great enough in the former level. By 1948 film methods of measuring exposure on a weekly basis had become practical and hence the maximum permissible dose was given as 0.3 r per week. Implicit in this is a belief that 0.3 r per week received at any time during the week is no more harmful than .05 r each day for six days.

By 1948 two new considerations had entered the picture. One was the shortening of life span which had been demonstrated in animals as the result of small daily doses of radiation, and the other was the genetic effects which were becoming more widely known and more positively established. It was felt at that time that so far as occupational exposure was concerned, the genetic factor should not be the limiting one, because of the relatively few people involved.

In the years between 1948 and 1954, when Handbook No. 59 was issued, a great deal of consideration was given to the problem of genetic effects of radiation. Geneticists D. R. Charles, H. J. Muller, and C. Stern, as members of the subcommittee on permissible external dose, exercised a great influence on the National Committee on Radiation Protection. However, it has been since that time that the genetic factor has loomed large because the hazard of fallout called attention to the radiation of the public at large. On looking into this matter of general radiation, the problem of medical exposures was brought to the fore.

Prior to the meeting of the International Commission in 1956, those interested in radiation protection began discussions of the gonadal dose received in diagnostic radiology by patients as well as those occupationally exposed. In the earlier periods, the accumulated doses to patients had not been taken into consideration because it was always assumed that diagnostic and therapeutic radiology consisted of medical procedures to be used on patients when they were needed for that patient's welfare. Under such conditions, their exposure was outside of the sphere of protection from occupational exposure. Two factors brought this matter of medical exposure to the increased attention of those interested in radiation effects. The first of these was the rapid increase in the number of people involved in medical radiation exposures. At the University of California Hospital, in 1934, 6 per cent of the patients in the clinic or the hospital on any one day had some roentgenologic procedure done upon them. In 1956, 30 per cent of this population had some type of roentgenologic procedure done upon them. Personal inquiry by Miller[18] indicated that this same increase was taking place in many hospitals across the country. Moreover, the complexity of the examinations and the number of projections used were increasing greatly. Since the total exposure of the gonads of all the population is the important factor in

genetic effects, it was obvious that if the non-occupationally exposed people were receiving more radiation, the occupationally exposed should receive less.

When the International Commission met in 1956, the three factors that were most influential in reducing the accumulated maximum permissible dose were the following:

1. While there are many uncertainties about the total effect of genetic changes, there is no uncertainty about the fact that such changes do exist and that they depend upon the total accumulated dose of the entire population.

2. While the fact of shortening of the lives of radiologists and others chronically exposed to radiation has not been proved beyond doubt, nevertheless, the fact that repeated exposure to radiation shortens the lives of animals is not a matter of doubt. It is quite likely that human lives can also be shortened, and that the amount of shortening depends in part upon the total accumulated dose.

3. The third factor is the need for rules of protection stated in more specifflc terms than in the past. Whereas it was stated in the past that the tolerance dose was 0.1 r per day, it was also stated that "It is strongly recommended that exposure to radiation be kept at the lowest practicable level in all cases." Now, however, business and industry are becoming involved in the matter of protection, and structures are having to be built in such a way that there will be constant levels of radiation in certain areas where people have to work daily for years. The engineers want to know whether it really is safe to have people exposed for eight hours a day, six days a week, to the amounts stated as the maximum permissible dose.

While occupational radiation exposure was mainly limited to medical facilities where radiologists kept the dose at the lowest possible level, and later to Government financed atomic energy plants where the cost for extra protection was paid by the Government, the aim had always been to stay within a certain figure—say, a third of the maximum permissible level—in order to be sure of not exceeding it. Now, with competitive industry involved, there must be some level to which all companies will have to build. Thus, in 1956, the International and National Committees felt that while a weekly tolerance of 0.3 r has not caused appreciable damage for occasional exposures, nevertheless a limit should be put to total accumulated exposure of 5 r in any year, and that the limit to those up to age thirty should also be put for genetic reasons at close to 50 r. Since that meeting of the International Commission, the National Research Council in this country and the Medical Research Council in Great Britain have issued reports that strongly support the steps taken.

It would seem that occupational exposure has been well taken care of by the precepts of the National Committee and the International Commission on Radiation Protection. The other problem brought up by the National Research Council, the Medical Research Council, and the Committee on Radiation Effects of the United Nations is that of the amount of radiation to the population from diagnostic and therapeutic radiation. The remainder of this presentation will be concerned with this phase of the subject.

The reports referred to above have, in general, pointed up the danger of the radiations used for diagnostic and therapeutic radiology but have neglected, in my opinion, to emphasize the tremendous benefits that have resulted from the use of roentgen rays. Professor Coller[5] has shown dramatically the debt of surgery to roentgenology. He pointed out that prior to 1895, the surgical operations carried out were on essentially the same conditions that Hippocrates could have diagnosed easily. Much of modern surgery, with all of its tremendous benefits to humanity, has come about because roentgenologic methods, along with others, have demonstrated clear-cut objectives for surgery, while the disease is still in a curable state. The opportunity for

surgeons was limited until roentgenology developed and made possible the diagnosis of lesions that surgeons could treat.

In 1900, the life expectancy of a newborn child was 49.2 years, while in 1950, it was 68.07 years[19] (Table II). While it is true that radiology cannot lay claim to being the major reason for this prolongation of life, it has played a not inconspicuous part in the development of modern medicine which is responsible for this great prolongation of life. Moreover, it should be noted that if there is a great danger to many lives being shortened as a result of increased medical use of radiation, it should have shown up by now, whereas in point of fact, each year life expectancy is increasing. One disease that has played a great part in shortening the lives of young people in the past has been tuberculosis, and here we find that whereas in 1900 the death ratio was 194 per 100,000 population, in 1955 this was only 9.1 per 100,000[19] (Table III). Diagnostic roentgenology has played its part in reducing the death rate due to tuberculosis.

Table II

LIFE EXPECTANCY AT BIRTH

1900–1902	49.24 years
1949–1951	68.07 years

Table III

TUBERCULOSIS AS A CAUSE OF DEATH[19]

Year	Ratio
1900	194.4 per 100,000
1955	9.1 per 100,000

Table IV

INFANT MORTALITY (DEATHS UNDER 1 YEAR)[19]

Year	Ratio
1915	99.9 per 1,000 live births
1955	26.4 per 1,000 live births

Table V

FETAL DEATHS (STILLBIRTHS)[19]

Year	Ratio
1945	23.9 per 1,000 live births
1955	17.1 per 1,000 live births

The geneticists rightly warn us of the danger of radiation which can cause increased fetal death and infant mortality as one of the early detectable effects. Yet, concurrently, with the great expansion in the use of roentgen rays, infant mortality has dropped from 99.9 per 1,000 live births in 1915 to only 26.4 in 1955.[19] Fetal deaths (stillbirths) have dropped from 23.9 per 1,000 live births in 1945 to 17.1 in 1955.[19] It has been stated that American children today are taller, healthier, and have a lower death rate than before the medical use of radiation began, and some of the figures would indicate that this is still continuing in the face of great expansion of the medical use of roentgen rays.

When considering the danger involved in the use of roentgen rays for medical purposes, we must evaluate them in relation to the other dangers of modern life. In 1955, motor vehicle accidents accounted for the lives of 38,426 people.[19] In contrast, March's[10] studies on deaths from leukemia among radiologists in the United States, were based on 14 deaths in twenty years, and some of these would probably have died of leukemia without exposure to roentgen rays. Among the 13,352 patients treated for spondylitis in Great Britain, the observed number of deaths from leukemia for the twenty year period 1935–55 was 25 as contrasted to an expected number of 2.4[12] These numbers are small compared to the deaths from motor accidents, yet we do not try to get rid of motor cars.

A method of comparing the genetic danger to our human race from allowing the mentally deficient to reproduce, with the genetic danger of using roentgen rays in medicine has not been developed. If geneticists would produce as much educational material on the dangers of propaga-

ting known mental defects as they are producing on the dangers of roentgen rays, they might accomplish even more for posterity than they are now.

The above comments are not intended as a means of minimizing or justifying the dangers of radiation, but in everything a balance must be struck between the benefits to be gained and the bad effects to be endured. There is no use in looking only at the bad effects. Those who emphasize or fear the bad results of diagnostic exposures often do not distinguish between total body exposure and local exposure when thinking of effects on the individual. Part of the misunderstanding is due to the peculiar nature of the unit of measurement called the roentgen. In stating the amount of an exposure in roentgens, too often no statement is made of the size of the area exposed. The "roentgen" is the measure of exposure to each gram of tissue and 1 roentgen to a toe is vastly different than 1 roentgen of total body exposure. This point should not need laboring to a group of radiologists.

It is well to remember that Kaplan[8] found that whereas whole body exposure produced leukemia in mice of a certain strain, partial body exposure would not produce leukemia even though an equivalent dose was given.

It must be admitted that much more attention has been given to the protection of those occupationally exposed to roentgen rays than to the patients; and while education in the hazards and the protective measures has been given to radiologists to some extent, little or none has been given to the vast numbers of others using roentgen ray equipment. There are estimated to be 125,000 roentgen ray machines in the United States. One-half of these belong to dentists, the other half to medical doctors, osteopaths, chiropodists, and chiropractors. In the State of California, the California Academy of General Practice, with 2,400 members, estimates that more than 50 per cent of them do their own diagnostic roentgenologic work. There is, therefore, a widespread and varied audience to be educated regarding the hazards to themselves and their patients, and the protective measures to be used. Radiologists should take a leading role in this program of education.

Diagnostic roentgen ray exposures are partial body exposures, and it is seldom that any one patient is exposed enough to do harm to him personally—even considering decrease of life span. The risk involved is, therefore, concerned with damage to the reproductive cells or to a developing embryo. Several studies in recent years such as those by Stanford and Vance,[18] Binks,[2] and Martin[11] have shown that examinations involving the lower abdomen and pelvis, while representing a small percentage of the examinations done in most offices and hospitals, account for a large percentage of the gonadal dose. What is not generally recognized is that practically every examination contributes something to the gonadal dose.

The aim of all professional men and women dealing in the healing arts must be to give the best possible service to their patients. This will involve keeping needed roentgen ray exposures to the minimum. The primary responsibility for the patient rests with the patient's private or clinic physician. That physician must be made aware of the risks of gonadal exposure, so that he will ask himself whether there is any way of reaching a correct diagnosis other than by roentgenologic examination. This admonition applies with particular force when the patients concerned are children, pregnant women, women in the childbearing period, and men below forty. The radiologist on his part must clearly understand the medical problem involved for every patient sent to him and keep the number of projections and repeat examinations to a minimum consistent with making the correct diagnosis.

There has been a great increase in the number of roentgenologic examinations requested, but this is not entirely due to medical developments. Some unnecessary examinations are made for one of several

reasons: (1) the patient has private or governmental insurance and wants that to which he feels entitled; (2) he is eligible for county, veterans, or other institutional care without cost to him, and therefore no limitation should be put on roentgenologic examinations; (3) legal complications and the court's demands for the fact of having been examined roentgenologically as a part of proper medical care account for many examinations; (4) the referring physician feels insecure in his diagnosis and differential diagnosis and wants confirmation. The only way to reduce the number of such examinations is to repeat and repeat that roentgenologic examinations must be limited by careful professional judgment to those required for the health needs of the patient.

Some examinations present greater problems than others. For example, roentgenography of children presents hazards to the patient and the staff. The patient is small and therefore the gonads are closer to every area that may be examined. The patient tends to move about and therefore larger cones are used frequently to be sure to get the desired area. It must never be forgotten that the child has a long life expectancy and many years to accumulate genetic effects from roentgen ray exposure before his parenthood days are over. Nevertheless, it is not uncommon to see the whole abdomen and the region of the gonads on roentgenograms made of the chest, or even of the skull. Another practice that should be discouraged or possibly prohibited is the fluoroscopic examination of well babies on their periodic visists to their pediatricians. Such examinations not only include almost as a routine the direct exposure of the gonads, but frequently the physician does not know the rate of exposure of the machine. Buschke and Parker[3] in 1942 and Sonnenblick[17] in 1952 found fluoroscopes with exposure rates varying from 2 r to 200 r per minute.

Pelvimetry examinations contribute as much as 20 per cent of the genetically significant radiation. They are a triple threat because they irradiate the gonads of the mother and the child, and if done early in pregnancy, may affect the embryo at the time of major organogenesis. They should not be done unless there is a threat to the health of the mother or child. If a pelvimetry study is necessary in the opinion of the obstetrician, it should be done late in pregnancy when the fetus is beyond the period of organogenesis and when a comparison can be made of fetal head size to pelvic size. The interesting suggestion has been made that women who plan to have children should see their obstetrician before becoming pregnant and if he finds that pelvimetry is needed, it can be done before onset of pregnancy. Bewley, Laws and Myddleton[1] make the practical suggestion that obstetrical roentgenography should be done only by the most experienced technicians in order to keep repeat exposure to a minimum.

Roentgenography of the pelvis of women who are pregnant but not aware of that fact is fraught with hazard to the embryo. Russell and Russell[16] have shown that there are critical periods, periods of organogenesis when doses as low as 25 r can cause demonstrable changes and lower doses may do so. This critical period is probably the second to sixth week of gestation, and pregnancy may be unsuspected during part of that time. The recommendation is made that all elective irradiation involving the uterus in women of childbearing age should be restricted to the two weeks following the last menstrual period in order to preclude the possibility of fertilization having taken place.

Many practical suggestions have been made by many authors of ways and means to reduce radiation to the gonads. That much can be done is obvious from the experience of the Dental X-ray Department at the University of California School of Dentistry. Whereas the literature shows skin exposures to the mouth area for "full mouth" examination of up to over 300 r,

Fitzgerald[7] reports that with higher kilovoltage, small well-defined beams, long distance and fast films, they have cut the full exposure to below 5 r.

Everyone using roentgen rays should constantly bear in mind the dictum of the Editor of the *Journal of the Faculty of Radiologists*:[6] Do not think of tolerance or maximum permissible dose, but of minimum possible dose.

CONCLUSIONS

1. The hazards of ionizing radiations and the need for protection have been known since 1896.

2. Increasing knowledge of the effects of radiation on animals has brought a lowering of the maximum permissible dose for occupational exposure in order to add factors of safety even though no one remaining within even the first established "tolerance dose" is known to have had appreciable bodily injury during his lifetime.

3. Genetic changes have become a greater and greater problem as more and more people have been occupationally and medically exposed.

4. Diagnostic roentgenology has been found to be a major source of irradiation of the gonads, but through the help it has given to modern medicine it has also played an important part in extending the life expectancy of all people.

5. Much more attention must be paid to lowering the gonadal dose by all of those engaged in the healing arts. Radiologists and all those using roentgen rays for diagnosis or therapy must always think of the minimum possible dose to the gonads.

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A SUMMARY: TODAY'S PROBLEMS IN RADIATION HAZARDS AND WHAT IS BEING DONE TO CONTROL THEM*

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AS A by-product of concern over the effects of fallout from thermonuclear weapon tests or the worse eventuality of thermonuclear warfare, public attention has been directed to the hazards of the medical use of ionizing radiations. These hazards are not new to us, as radiologists, but there are some new features about them which deserve our consideration. There has been some distortion and misplaced emphasis as to the extent of hazards in medical radiation, but there has also been reasonable advice on some radiation precautions. Some good recommendations have been made, as well as some ill-advised and impractical ones. What then is to be the outcome as this problem is posed? Are roentgen rays too dangerous for the future of the race to outweigh the good when used in medical diagnosis on those below the age of thirty or forty? Should medical radiologic departments and offices be forbidden territory to all except the terminally ill and aged? Should we consider that a minute bank account of radiation exposure must not be overdrawn for the individual patient? Ought radiologists and their coworkers forsake their occupation for Tahiti while they still have a little time to live? These are absurd excesses that have not been the intent of any serious group that has been studying today's problems in radiation hazards and what should be done to control them.

But there is need for intelligent thought and action. Some uses of radiation in medicine should be re-evaluated; some radiation exposures are higher than is necessary in obtaining needed information. Only by critical re-examination and appraisal can the needed changes be effected. In the contributions of this symposium, the basis for such discriminating assessment has been clearly presented and plans for sound action have been outlined.

The basic information on radiation hazards is not of uniform reliability. Some has the authority of well known and proven fact. Some has been derived from less precise experimental and statistical evidence that is not susceptible to further proof at this time. Some should properly be considered as conjecture, interesting or even brilliant, but debatable. Offering such unequal certainties as the bases for positive action, they must nevertheless be used as the best that we have at this time. This is no unique situation for the physician who is already conditioned to the weighing of evidence, but it complicates the reduction of protective measures into a simple set of rules which might be suitable for general and noncritical use.

The well known and generally accepted facts deserve frequent repetition. They have been the theme of national and international committee recommendations, of numerous contributions to scientific meetings and journals, and of our teaching that: (1) The exposure of human beings to ionizing radiation always involves potential hazard, regardless of beneficial purpose. The hazards are both somatic and genetic. (2) Radiation dosage should be kept as low as possible while accomplishing the desired medical diagnostic or therapeutic aim. (3) Education and experience are needed for each decision of medical usefulness versus hazard and for close control of radiation dosage. (4) The development and use of improved techniques, instruments, and apparatus has reduced and continues to

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reduce radiation exposure. (5) The medical indications for radiologic procedures are subject to changing factors and should be reviewed constantly in the light of advances from all branches of science.

The development of radiation protection along these lines has been a gradual evolutionary process. Dr. Stone has well illustrated the historic background and perspective of this growth. The best of current information is not always applied uniformly by all members of the medical profession, but advance has been consistent during the past sixty years and accelerating during the last twenty years of medical use of radiation.

New findings, new evidence, and new interpretations deserve serious attention. In this symposium, the most important ones have been discussed in some detail, with critical regard to the reliability of each consideration. Important features from these can be summarized as follows:

1. The quantitative level of radiation which may significantly affect the genetic future of populations is now thought to be lower than formerly, from the best genetic experimental evidence.
2. From similar experimental evidence, there appears to be no radiation exposure threshold for the genetic hazard to populations.
3. Life shortening effects on the individual human being should be included in the considerations of radiation hazard. On best experimental analysis they do not seem excessive, but they cannot be ignored.
4. There are evidences that low levels of radiation exposure may have greater somatic and genetic consequences during infancy and childhood.
5. The medical use of radiation is increasing and is now approaching the point where its hazards have become a population problem as well as an individual one.
6. The amount of radiation exposure of the population is not known, its precise estimation is extraordinarily difficult, and, to be of scientific value, its study must be comprehensive, considering differential exposures of the portions of the body as well as whole body exposure.
7. The present exposure to radiation for medical and dental purposes can be appreciably reduced by techniques and methods that are already available. These are economically feasible and largely require only interest, education, and the use of well established information and instruments.

These do not seem to be revolutionary concepts, but rather the logical further evolution of fresh thought in the long range growth of our knowledge in radiation protection. They furnish no ready or complete answers to the daily and individual choice as to the advisability of radiologic procedures, diagnostic or therapeutic. They do, however, focus attention on the use of optimal techniques and add new quantitative factors to the critical assessment of radiation exposures employed both for sick patients and for elective and survey examinations.

Many things have *not* been said. There has been no statement that any specific medical radiologic procedure should be prohibited, but rather that the needs and indications for each should be weighed against the hazards. Even this qualification must not be too rigid, for some examinations instigated by a mental process approaching intuition, in an experienced mind, have proven exceptionally rewarding. There has been no statement that there are too many radiologic examinations and that the total number should be reduced. To the contrary, it is probable that an increased use of radiologic diagnosis will work to the total benefit of the population, though this is reasonably possible within a reduced total radiation exposure. It has not been advised that radiologists and their co-workers should have excessive concern for their longevity or the harmful effects of radiation on themselves as in-

dividuals, provided they adhere to modern protective standards. Rather it seems that some of the publications on this subject have been unduly pessimistic. There has been no statement that every individual should carry a diary of all man made radiation exposure. Some of the complexities and dubious worth of such records have been apparent in the discussion of the physical factors involved and these become compounded by medical considerations to a nearly vanishing return. Limited and controlled statistical studies, however, may well furnish needed scientific information for the future. The answers to our problems are not yet simple and many specific ones are not available. Exact values cannot yet be assigned to the precise individual risks of the absorption of a given number of gram rads in a specified volume of tissue. Even less attainable is a measured value for the human beneficial returns from such exposure.

What practical advice and guides for action, then, can we draw from this best of current and past knwledge? The physician using radiation should look to:

1. *What apparatus is used for radiation exposure?* The cones should limit the beam to the desired area or film and they should have no marginal leakage. Adequate added filtration should be employed. The radiation output should be determined and known for the various conditions of use.
2. *Who is being exposed?* Think of the individual person whenever undertaking a procedure, especially those on children, pregnant or potentially pregnant women, and, in fact, anyone below the age of 40.
3. *Where is the exposure given?* Recognize the additional hazard when the gonads are included in the primary beam and when large volumes of the body are exposed.
4. *How much exposure is given?* Devote special attention to extensive examinations involving large amounts of radiation and to repeated procedures. Consider both local and integral radiation dosage.
5. *Why is radiation exposure used?* There should be good and adequate reason, a purpose based on medical judgment, in the decision to do any procedure at a given time.

The users of radiation in the healing arts bear impressive responsibilities. These include vigilance in preventing unwanted exposure of the public, patients, and radiation workers, while yet allaying undue fear on the part of each. Education of all is a continuing obligation, so that our total knowledge may be extended to its fullest use. To do our work with all of the skill and care that is attainable is the most effective of all measures in radiation protection. This is not to be achieved by legislation or rigid rules, by exhortation, or even fear, but proceeds from the individual mind which employs wisdom, experience, and common sense.

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COARCTATION OF THE ABDOMINAL AORTA AT THE ORIGIN OF THE INFERIOR MESENTERIC ARTERY

REPORT OF A CASE DIAGNOSED BY TRANSLUMBAR AORTOGRAPHY

By TAWAN SURAWONGSE BUNNAG, M.D.
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COARCTATION of the abdominal aorta is not a disease process of usual occurrence; therefore, the condition sometimes fails to enter the differential diagnosis in the clinician's mind. Symptoms and signs of deficient blood supply to the lower extremities often lead to the supposition of thrombosis or aneurysm before that of coarctation. Only a roentgen demonstration of the real pathologic condition will quickly and definitely establish the diagnosis without surgical exploration.

The few cases reported in the literature of coarctation of the aorta at unusual sites fall under Sloan and Cooley's classification of Type III group.[7] In these the coarctation varies widely as to location and the abdominal aorta forms a minority. Twelve cases have so far been reported. The first one, in which there was a stenosis of the abdominal aorta below the origin of the visceral arteries, was described by Power in 1861. Maycock, in 1937, reported a coarctation at the origin of the renal arties; Baylin, in 1939, described a coarctation distal to the orifice of the renal arteries. Steel, in 1941, reported a coarctation above and at the level of the renal arteries and in another case immediately below the diaphragm; Bahnson, Cooley and Sloan[1] reported coarctation at the origin of the renal arteries in 1949; Kondo and co-workers[5] in 1950, reported 1 case of coarctation between the celiac axis and the renal arteries. Martin and Yount[6] quoted a case reported by Goldzieher and co-workers in 1951, again at the origin of the renal arteries, and 3 other cases without clinical data, 1 quoted by Bahnson in 1948, 1 reported by Wang in 1949, and a third case reported by Abanese and Baila in 1953. The twelfth case was reported by Martin and Yount[6] in 1956.

In many of the above cases the diagnosis was made at autopsy. In others the diagnosis was made by angiocardiography and aortography.

REPORT OF A CASE

Our case is that of a twenty-two year old single female Siamese, who came to the hospital in November, 1955 with complaints of intermittent claudication, manifested by weakness and numbness of the lower extremities, especially after long walks. The symptoms forced the patient to stop for rest, then they would disappear.

These symptoms had been noted several years before admission; however, they worsened in the past one and a half years. Weakness and numbness began in the feet, then ascended gradually to the hips and waist. Usually, a rest period of about fifteen minutes was necessary before normal strength and feelings to the lower extremities returned.

Her past history revealed that she had had fever and chills which lasted about two months when she was eighteen years old.

The physical examination showed a well developed, well nourished female with a healthy general appearance. The positive findings were: a systolic murmur and systolic thrill at the level of the umbilicus; normal pulsation of the iliac arteries; weak femoral pulse; no pulsation of the popliteal, posterior tibial, anterior tibial and dorsalis pedis arteries. The blood pressure in the right arm was 140/70, that in the left arm was 144/80. Blood pressure in the lower extremities could not be measured with ordinary manometric cuffs.

Blood Wassermann and Kahn tests were negative. The blood hemoglobin was 12 gm. per cent. The red blood cell count was 4.3 million; the white blood cell count was 7,500 with a differential count of 70 polymorphonuclear leuko-

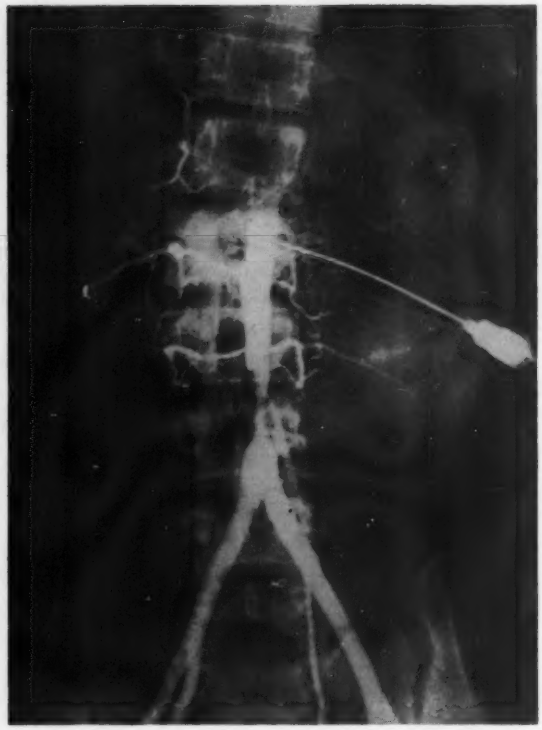

FIG. 1. Aortogram taken 4 seconds after beginning of injection. Coarctation between L2 and L3, involving the origin of the inferior mesenteric artery.

cytes, 25 lymphocytes and 5 eosinophils. The blood chemistry and urine examination were normal.

A clinical diagnosis of aneurysm of the abdominal aorta was made. Differential diagnoses were thrombosis of the distal aorta and, also, coarctation of the abdominal aorta.

A roentgenogram of the chest disclosed no abnormal findings. A translumbar aortography was performed. The contrast medium, 20 cc. of 70 per cent urokon, was injected at the level of L1; serial roentgenograms were made, using intervals of one-half second and starting about three seconds after the beginning of the injection. The roentgenograms showed narrowing of the abdominal aorta between the level of L2 and L3 of about 4 cm. length, which included the origin of the inferior mesenteric artery and the arteries of L3. Roentgenograms also demonstrated the right renal artery and vein, the latter emptying into and opacifying the inferior vena cava. The left renal artery and vein were only faintly visualized; a plexus of veins in the lumbar region was opacified; the lower right intercostal arteries, the iliac arteries and their bifurcations were well visualized and there was also a faint opacification of the midsacral artery (Fig. 1, 2 and 3).

At this time a diagnosis of coarctation of the abdominal aorta at the level of L3 and L4 involving the origin of the inferior mesenteric artery was made.

Because the coarctation involved the origin of the inferior mesenteric artery, no graft, but a lumbar sympathectomy was contemplated. The patient, however, refused operation and returned home without exploration.

The patient came back about a year later to announce that she was quite well. Her attacks of numbness in the lower extremities were not aggravated, but subjectively, she thought they had become milder since the translumbar aortography. The patient appeared so well physically and in spirit that nothing was done to her at this time that might prove psychosomatically disturbing.

DISCUSSION

It is evident from the literature that there seems to be no definite line of demar-

FIG. 2. Aortogram taken 4.5 seconds after beginning of injection. Coarctation involves the origin of L3 arteries.

cation between coarctation of the aorta at the usual and unusual sites based on the clinical features, such as hypertension in the upper extremities, hypotension in the lower extremities, intermittent claudication and signs of heart failure including palpitation, dizziness, dyspnea, nausea and precordial pain. Only the systolic murmur in the abdomen ranging in distribution from the epigastrium to the level of aortic bifurcation seems to favor a diagnosis of coarctation in the abdominal aorta. This is sometimes also heard in cases of coarctation in the thoracic aorta; however, finding of a normal chest and mediastinal contour favor the atypical position of the coarctation.

Our case presented no change of the left border of the mediastinum nor was there evidence of notching in the ribs. This led to exclusion of coarctation at the typical site. There was definite evidence of lower peripheral circulatory deficiency. Blood pressure in the lower extremities was so low that it could not be measured, and the systolic murmur and systolic thrill at the level of the umbilicus were very distinct. While the systolic murmur and thrill led the internist to strongly suspect an aneurysm of the abdominal aorta, the circulatory failure led the surgeon to consider thrombosis of the distal abdominal aorta, and also, but only lastly, coarctation.

Coarctation at the level of the renal arteries and at higher levels has been reported many times. So far, no case has been presented with involvement of the origin of the inferior mesenteric artery. The present case appears to be first in this respect, although Power's case in 1861 described a coarctation still more distal in location.

As for the etiology of the condition, the literature mentions congenital maldevelopment. Other causes cited are: extrinsic pressure by a neurofibroma in a case with Recklinghausen's disease,[3] inflammatory changes about the aortic stenosis,[1] and organized thrombosis with recanalization of the aorta as described by Hasler.

In our patient, a middle class, conservative, oriental country girl who grew up quietly in her home, the symptoms were first noticed when she was mature enough to undertake some household and business activities by herself. The symptoms were especially pronounced on physical exertion and they gradually increased as her activities increased. Although it is possible that the coarctation in our patient could be congenital, it is difficult to conceive that childhood activities, even in a conservative milieu, did not bring about signs and symptoms at an earlier age, if it were so. On the other hand, it should be noted that at the age of eighteen, the patient had suffered from chills and fever for a duration of about two months, which seems to agree well with the time of onset of her symptoms. These facts lead to the assumption that the coarctation was acquired.

Fig. 3. Aortogram taken 5 seconds after beginning of injection.

It is evident from this case report that the exact diagnosis, and, better still, the localization of the site of the coarctation could not have been made without arterial

opacification. The choice of the procedure will depend on the clinical aspect of the disease. We have not hesitated to use translumbar aortography in our case because the procedure is relatively simple, and the signs and symptoms have led us to consider three pathologic conditions of the abdominal aorta in the differential diagnosis, namely: aneurysm, thrombosis and coarctation. It is true that no operative procedure was undertaken, but the roentgenographic findings are so definite that we feel that they are sufficient evidence for accepting the diagnosis.

SUMMARY

A thirteenth case of coarctation of the abdominal aorta diagnosed by translumbar aortography and the first case with involvement of the origin of the inferior mesenteric artery is described, with review of the literature and a discussion of symptomatology, etiology and diagnosis.

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I wish to express my thanks to Dr. Jai Yunibandhu, medical consultant to the Chulalongkorn Hospital, who referred the case to us and Dr. Chalia Vajarabukka of the Department of Surgery, without both of whose interest and investigation this case would not have been disclosed; also to members of the radiological department whose enthusiastic cooperation is deeply appreciated.

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A TRUE AND A FALSE ARTERIOSCLEROTIC ANEURYSM OF THE SUBCLAVIAN ARTERY*

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ARTERIOSCLEROTIC aneurysms of the subclavian artery are very rare. Indeed, McCallen and Schaff[3] in 1956, in reporting an arteriosclerotic aneurysm of an anomalous right subclavian artery stated that search of the literature failed to reveal previous cases. In recent years, longevity has resulted in an increased incidence of arteriosclerotic thoracic aneurysms;[1,2] accordingly, increase in brachiocephalic artery aneurysms due to arteriosclerosis may also be anticipated.

In the cases herein reported, an arteriosclerotic aneurysm of the left subclavian artery in association with severe thoracic and abdominal atherosclerosis and aneurysms were present in one patient. In the other, severe generalized atherosclerotic disease with rupture of a calcified intimal plaque in the right subclavian artery resulted in a false aneurysm in the superior mediastinum. Subsequently, massive fresh hemorrhage into the mediastinum and right pleural cavity was fatal. The purpose of this report is to correlate the clinical and roentgen features of arteriosclerotic subclavian artery aneurysms, and thereby, establish the criteria for their recognition during life.

REPORT OF CASES

CASE 1. *Arteriosclerotic Aneurysm of the Left Subclavian and Axillary Arteries Associated with Thoracic and Abdominal Aortic Aneurysms.* A sixty-four year old housewife was referred to St. Francis Hospital and Sanatorium by Dr. Robert W. Duffy on August 17, 1956 complaining of abdominal pain and backache. Seven years prior to entry, recurrent attacks of backache radiating to the abdomen began; examination disclosed an abdominal mass. However, the patient remained fairly well for a year until easy fatigability and weight loss began. A week before admission, a translumbar abdominal aortography had been done at another hospital; immediately following severe abdominal pain and backache set in.

On examination the patient was in moderate distress. She was afebrile; the right arm pulse was regular, of good quality, rate 74, and blood pressure, 120/86 mm. Hg. The left pulse was not palpable. There was a systolic murmur over the aortic area. The neck vessels, however, were not pulsatile. A large, tender midabdominal mass about 10 by 10 cm. was felt. The lower extremity pulses were of good quality and the legs were warm and normal in appearance.

The abdominal aortogram, made at another hospital, showed a huge abdominal aneurysm containing laminated thrombus and calcium. The aneurysm appeared to involve the renal arteries, although a pyelogram showed some filling of the right kidney pelvis. The chest roentgenograms (Fig. 1, *A* and *B*) revealed slight cardiac enlargement. There was tortuosity and unfolding of the thoracic aorta and the aortic knob contained calcium. Widening of the superior mediastinum was evident; the left apex and infraclavicular area contained calcific deposits (Fig. 1*C*).

On August 22, 1956, an abdominal exploratory operation disclosed a huge aortic aneurysm beginning at the celiac axis, involving both renal arteries, and extending to the iliac bifurcation. Resection could not be done because of renal artery involvement. Subsequently, coldness and loss of arterial pulsation of the left leg developed. A clot was removed from the left femoral artery with return of color, warmth, and pulsation in the left leg. However, the blood urea nitrogen became elevated and the patient died on the fourth postoperative day.

At autopsy,† the heart was enlarged and weighed 460 gm. The coronary ostia were widely patent but the coronary arteries showed

† Performed by Dr. Leslie Lukash.

* From the Departments of Radiology, The New York Hospital-Cornell Medical Center, New York, New York and St. Francis Hospital and Sanatorium, Roslyn, New York.
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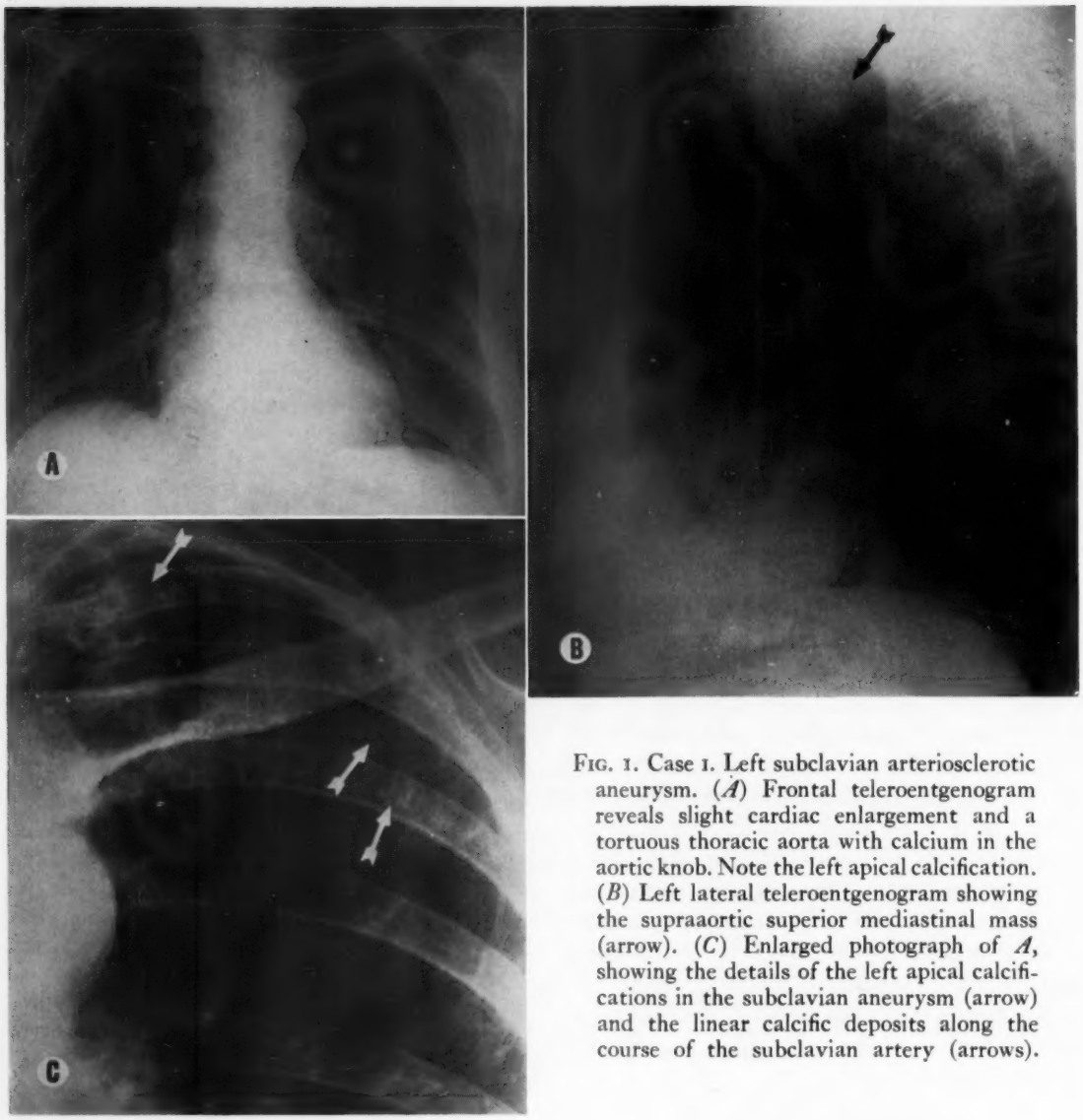

FIG. 1. Case 1. Left subclavian arteriosclerotic aneurysm. (*A*) Frontal teleroentgenogram reveals slight cardiac enlargement and a tortuous thoracic aorta with calcium in the aortic knob. Note the left apical calcification. (*B*) Left lateral teleroentgenogram showing the supraaortic superior mediastinal mass (arrow). (*C*) Enlarged photograph of *A*, showing the details of the left apical calcifications in the subclavian aneurysm (arrow) and the linear calcific deposits along the course of the subclavian artery (arrows).

intimal atherosclerosis with approximately 40 to 80 per cent narrowing of the lumen in many sections. The thoracic aorta was slightly widened and showed considerable atheromatous changes with calcifications in several of the plaques. Posteriorly, at the level of the sixth, eighth and tenth intercostal arteries, arteriosclerotic saccular aneurysms measuring approximately 2–4 cm. in diameter were present. The innominate and left common carotid arteries were normal in size and appearance. In marked contrast was a saccular aneurysm of the left subclavian artery which measured 3 cm. in diameter (Fig. 1, *D* and *E*). The continuation of the vessel (left axillary artery) was dilated, there being three saccular dilatations with markedly calcified wall and with the lumen narrowed by laminated blood clot. The abdominal aorta was markedly sclerotic and contained an extensive aneurysm extending from the renal to the iliac arteries; there was also a large saccular aneurysm of the right iliac artery.

CASE II. *False Aneurysm with Mediastinal and Right Pleural Hemorrhage Due to Rupture of an Arteriosclerotic Plaque, Right Subclavian Artery.*

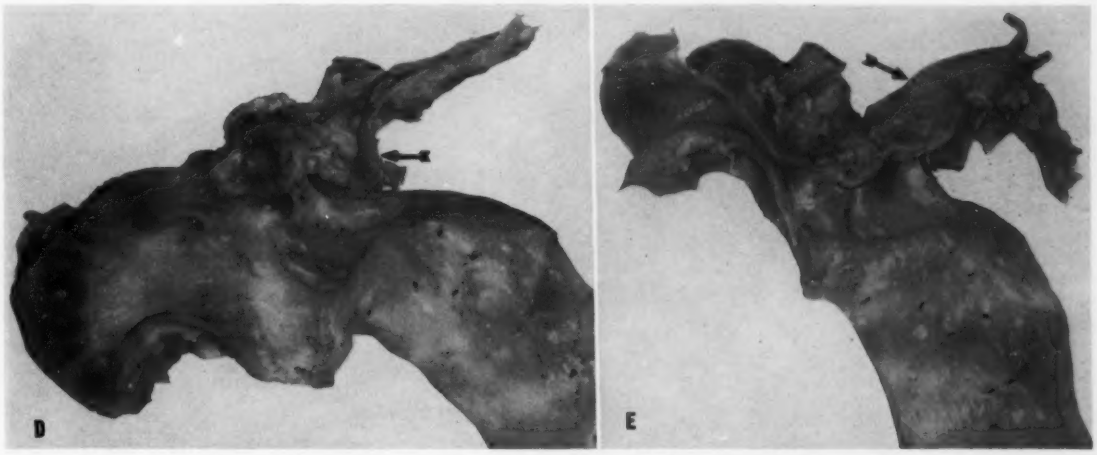

Fig. 1. Case 1. (*D*) Postmortem specimen showing the opened aortic arch revealing an interior view of the left subclavian artery aneurysm (arrow). Note the atherosclerotic plaques throughout the aorta. (*E*) Posterior view of the left subclavian aneurysm (arrow).

A seventy-eight year old white retired female nurse (N.Y.H. No. 94419) was referred to The New York Hospital by Dr. Seymour Advocate on April 4, 1956 because of mental confusion and abdominal cramps. She had been seen in the clinic in 1935, at the age of fifty-seven years, for painful swollen finger joints of both hands. Physiotherapy afforded relief for many years. In 1951, there developed severe, painful and swollen knees; osteoarthritic changes were found on roentgen examination. The cardiac rhythm was totally irregular but was reverted to regular sinus rhythm after treatment with quinidine. The blood pressure readings ranged from 102/65 to 170/94 mm. Hg. The peripheral vessels were sclerotic. A chest roentgenogram showed an enlarged left ventricle with sclerotic, tortuous brachiocephalic arteries and an elongated aorta. Roentgen examination of the extremities revealed severely calcified vessels. There were no cardiac murmurs and no signs of congestive heart failure. For the next five years she had not visited the clinic. On March 25, 1956, she was admitted to another hospital because of loss of memory and nervousness; transfer was then made to The New York Hospital.

On examination the patient was febrile (39° C.); had a totally irregular pulse of 80; the blood pressure was 150/90 mm. Hg. She was thin, chronically ill and lethargic with a weak voice. She was disoriented and the ocular fundi exhibited tortuous vessels with marked arteriovenous nicking without exudates or hemorrhages. There was increase in the posteroanterior diameter of the chest; the lungs were clear except for a few inspiratory rales at the left base. The heart was enlarged to the left, the sounds were of good quality, and the aortic second sound was louder than the second pulmonic sound. A rasping systolic murmur was heard over the whole precordium, loudest to left of the sternum. The abdominal examination was unremarkable. The abdominal aorta was palpable, normal in size and unduly pulsatile. Ankle jerks were absent but other abnormal neurologic signs were absent. Marked sclerosis of the vessels of the extremities was again noted.

Laboratory studies including blood, urine and spinal fluid examinations were normal except for a white blood cell count of 14,800. Roentgenograms of the chest (Fig. 2, *A* and *B*) showed an enlarged left ventricle with an unfolded and sclerotic aorta. A right superior mediastinal mass with linear calcifications along the upper and posterior margins was present, having developed since the 1951 examination; the lungs were clear and the trachea was in the midline. The electrocardiogram revealed auricular fibrillation with left ventricular hypertrophy.

Because of high fever, antibiotics were given but the fever persisted, ranging between 36.8°C. to 38.8°C. daily. Digitalis was also prescribed. On the eighth hospital day, sudden dyspnea and apprehension appeared but without change in blood pressure. The respirations were 30 per minute; the quality of the pulse remained good, rate 110 and irregular. No abnormal physical signs were elicited in the chest. The following

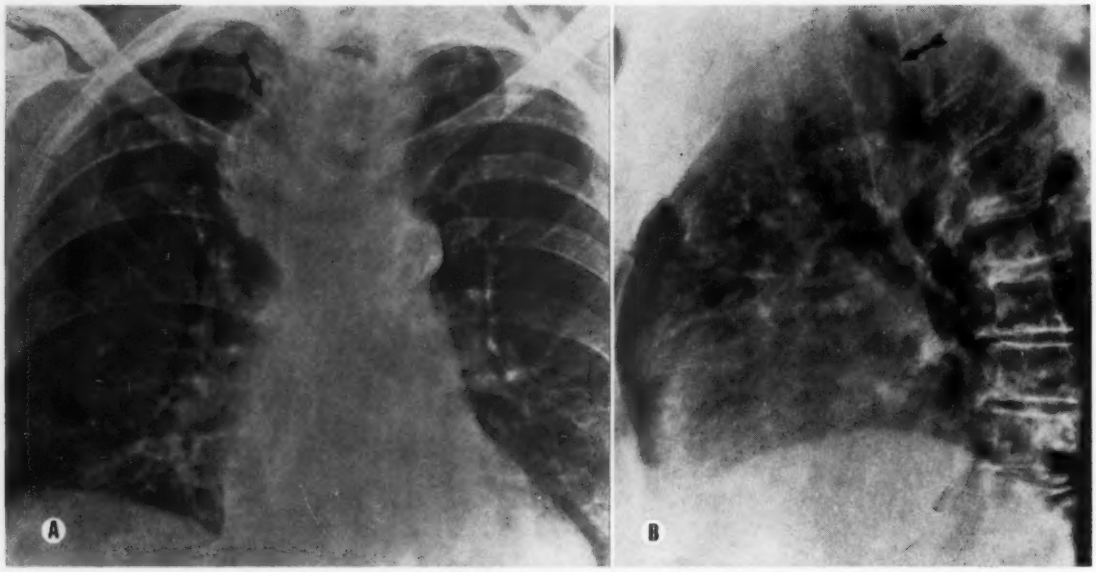

FIG. 2. Case II. False aneurysm of the right subclavian artery. (*A*) Frontal teleroentgenogram showing enlargement of the heart and a tortuous, unfolded arteriosclerotic aorta containing calcium at the knob. Note the right superior mediastinal mass with calcium at the upper pole (arrow). (*B*) Left lateral roentgenogram with the superior anterior mediastinal mass (arrow) lined by calcium along its posterior margin.

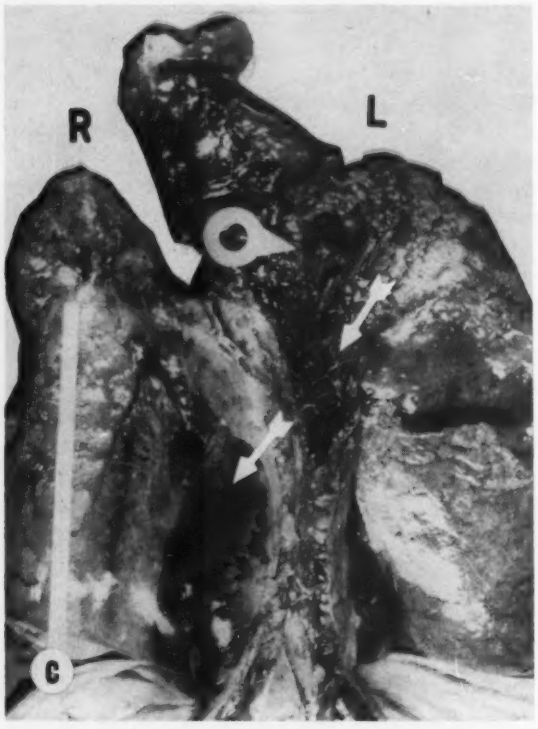

FIG. 2. Case II. (*C*) Postmortem specimen showing the location of the false aneurysm (arrow). Notice the mediastinal and right thoracic hematomas (arrows). The right (R) and left (L) lungs are seen *in situ*.

day, dyspnea and apprehension recurred; cyanosis was present and a loud "croaking" noise was heard over the larynx. Similar attacks recurred three to four times during the night. Laryngoscopy showed the air-way to be clear. An hour later, there was another "choking" attack and breathing ceased. The patient became intensely cyanotic and failed to respond to artificial respiration.

At autopsy,* there was rupture of an arteriosclerotic plaque in the right subclavian artery with massive mediastinal and right pleural hemorrhage. A rent in the posterior wall of the right subclavian artery measured 7 by 2 mm. and was located at the junction with the right common carotid artery. The lumen of the right subclavian artery communicated with a spherical cavity 5 cm. in diameter, walled off from adjacent structures by a layer of partially organized blood measuring 0.5 to 1.0 cm. in thickness. A mediastinal hematoma extended into the prevertebral and medial cervical fascia embedding the esophagus, large vessels, and nerves of the neck. Seven hundred cc. of partially clotted blood was present in the right pleural cavity (Fig. 2*C*).

The heart was enlarged and weighed 420 gm.; the left ventricle wall measured 20 mm.

* Performed by Dr. Gleb Bridzalovich.

and the right, 3 mm. in thickness. The leaflets and cusps of the mitral and aortic valves were thickened by focal arteriosclerotic plaques. The walls of the coronary arteries were extensively calcified, and their lumina markedly narrowed. The walls of the aorta and major arteries were severely and extensively altered by numerous arteriosclerotic, calcified and eroded plaques. Arterionephrosclerosis was also present. Histologically, all the large arteries were extremely atherosclerotic; all vessels having thinned media and coalescent, eroded and calcified intimal plaques.

DISCUSSION

Tortuosity and calcification of a subclavian artery with masses containing calcified thrombus at its origin are apparently significant clues for the diagnosis of an ateriosclerotic aneurysm (Fig. 1, *A*, *B* and *C*). If, as in Case 1, there is also absence or diminution of the pulse and widespread generalized atherosclerosis involving other vessels, the diagnosis seems certain.

In contrast to Case 1, in which the arteriosclerotic aneurysm of the left subclavian artery was an incidental finding, the rent in the right subclavian artery in Case II was lethal and produced a false aneurysm that masqueraded as a right superior mediastinal tumor (Fig. 2, *A* and *B*). Death was apparently due to hemorrhage and asphyxia. Retrospective analysis indicates that fever of unknown origin, localized calcium plaques in the right subclavian artery, and generalized atherosclerosis of the peripheral arteries were significant, although nebulous clues.

In Case 1, the definitive diagnosis of left subclavian artery aneurysm might have been made by angiocardiography. However, the poor general condition of the patient precluded such studies. Angiocardiography was recommended in Case II but again could not be done because of the critical condition of the patient. It is doubtful that the false aneurysm could have been diagnosed by roentgenography alone. The most that might have been revealed by angiocardiography is buckling of the subclavian artery.

SUMMARY

Two elderly women with subclavian artery aneurysms, one with a previous history of hypertension, but both with widespread generalized atherosclerosis of the aorta and peripheral branches are reported. In one, there was a true, although incidental aneurysm of the left subclavian artery; death followed an abdominal operation that disclosed an inoperable abdominal aortic aneurysm. In the other, a false superior mediastinal aneurysm resulted from rupture of an arteriosclerotic plaque in the right subclavian artery. Death was due to asphyxia from a mediastinal and right pleural hematoma.

In the patient with the true left subclavian artery aneurysm, significant clues were present in the chest roentgenogram. These consisted of tortuosity of the brachiocephalic arteries, a calcified mass at the origin of the subclavian artery, and linear calcification along the route of the subclavian artery. In the patient with the false aneurysm, an enlarged right superior mediastinal mass, calcium plaques in the right subclavian artery, and widespread generalized peripheral arteriosclerosis were the only significant hints in the roentgenograms.

CONCLUSIONS

A high index of suspicion of the presence of a brachiocephalic arteriosclerotic aneurysm is necessary when superior mediastinal masses are present in the chest roentgenograms of patients in the arteriosclerotic age group. This is particularly important if there is generalized atheroma of the peripheral arteries. Tortuosity, buckling and elongation of the brachiocephalic and thoracic aorta are usually also present. If there is calcification of the superior mediastinal mass at the origin of the vessel and along its course, the diagnosis of aneurysm becomes presumptive. Angiocardiography will provide the definitive diagnosis.

Diagnosis of a false aneurysm of a brachiocephalic vessel is more difficult. In the absence of calcification, clinical evi-

dence of change in voice, tracheal compression or hemorrhage become important clues.

The diagnosis of a brachiocephalic artery aneurysm is important because of its tendency to rupture. Now that suture of arteries, resection and replacement by homologous grafts are feasible, early recognition may be life saving.

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THE EFFECTS OF SUSTAINED DEEP INSPIRATION ON THE NORMAL LOWER ESOPHAGUS AND PHRENIC AMPULLA IN ERECT ADULTS*

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THE distal portion of the esophagus presents variations in configuration which merit further roentgenologic consideration. On gross specimens a dilatation designated as the phrenic ampulla may be identified proximal to the inferior esophageal sphincter. The roentgenologic configuration of this dilatation is variable, and differs from patient to patient as well as from moment to moment in the same individual. The lower esophagus is physiologically, as well as anatomically, different from the remainder of the tube. Considered as the "gastroesophageal segment of expulsion," it is composed of the phrenic ampulla above the inferior esophageal sphincter, the gastroesophageal vestibule beneath this sphincter and above the constrictor cardiae, and the phrenoesophageal elastic membrane which loosely attaches this area to the diaphragm.[4]

The distal esophagus traverses the esophageal hiatus of the middle leaf of the diaphragm. Situated to the left of the midline, the hiatus is made up mainly, if not entirely, by the right crus of the diaphragm. This is longer, thicker and more tendinous than the left. Arising from the upper three lumbar vertebrae, it separates into superficial and deep muscular layers. The thin superficial layer forms the right margin and the thick deep layer forms the left margin of the hiatal ring. The anterior margin of the ring is close to the tendinous portion of the middle leaf, and posteriorly the hiatus is partially occluded by a thin veil of decussating muscle fibers and fibroareolar tissue. The relative level of the esophageal hiatus varies considerably, as do the size and strength of its muscular components.[5] The disposition of the gastroesophageal vestibule is quite variable, particularly insofar as its infradiaphragmatic component is concerned. Indeed, this portion of the esophagus changes its position normally with relation to the esophageal hiatus, and is influenced by changes in gastric filling and position. Because of this the diagnosis of a small sliding hiatal hernia may be difficult.

A "pinch-cock" muscular action of the crura of the diaphragm against the hiatal portion of the esophagus has been considered the causative factor in the formation of the phrenic ampulla. Recently evidence has appeared which questions this theory. Dornhurst, Harrison and Pierce[2] were unable to substantiate such an action in a physiologic investigation of the lower esophagus utilizing combined roentgenologic and transducer pressure-recording experiments. Further evidence was obtained by noting that fingers placed within the esophageal hiatus at operation during contraction of the diaphragm produced no pressure effects. Zaino, Poppel and Blazsik[9] and Poppel, Zaino and Lentino[6] concluded that the esophageal hiatus merely accommodated the passage of the esophagus without influencing its action. Braasch and Ellis[1] stated that the diaphragm was unimportant in the mechanism of gastric competence. Their experiments on dogs indicated that the site of this function was the esophagogastric junction.

It has been recognized that the phrenic ampulla is seen better on deep inspiration. However, the effects of a sustained deep inspiration on normal erect adults require further investigation inasmuch as previous studies have been made mainly with patients recumbent.[3,5,6,8]

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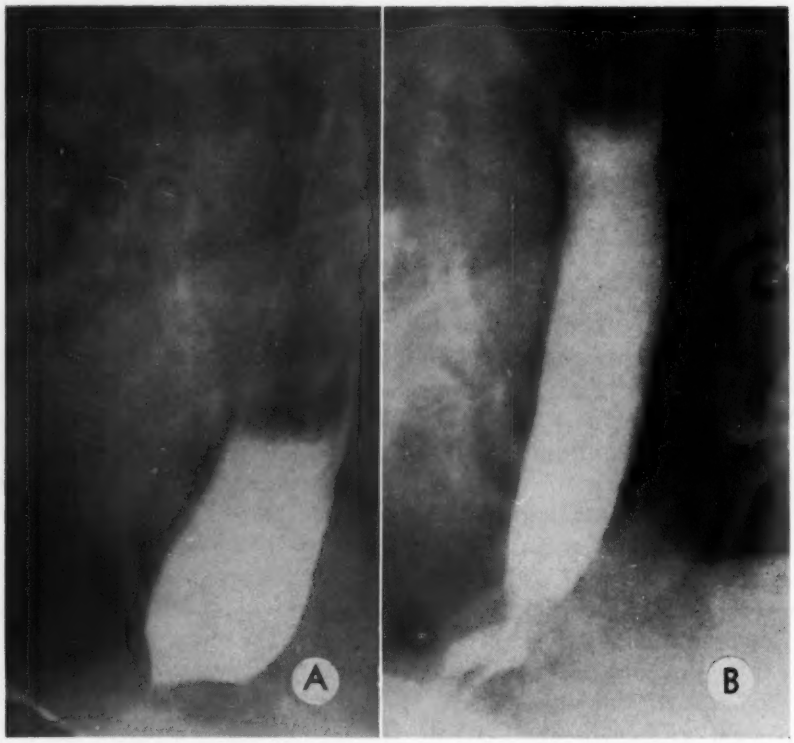

FIG. 1. Erect spot roentgenogram immediately after swallowing three mouthfuls of barium and taking a deep breath. Note the tapered tip of the esophagus and the diffuse dilatation with fluid level (*A*). With maintained inspiration retroperistalsis pushes the barium back into the esophagus and a small amount enters the stomach (*B*).

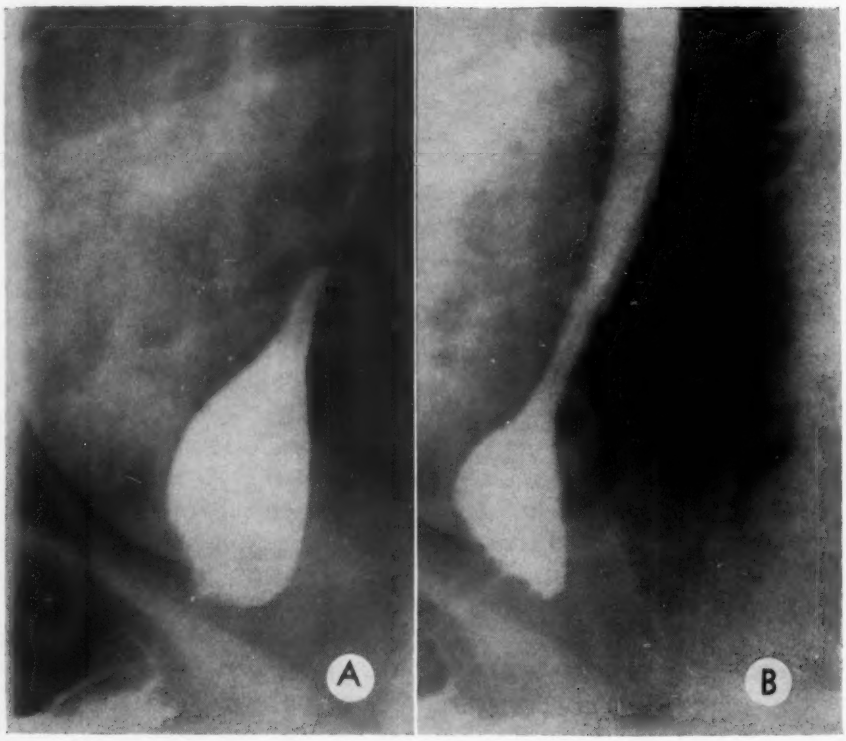

FIG. 2. A phrenic ampulla is formed immediately after deep inspiration. Note the tapered upper aspect of the ampulla (*A*). With maintained inspiration retroperistalsis pushes barium back into the esophagus. Note the change in the configuration of the distal esophagus (*B*).

The behavior of the esophagus during sustained inspiration was examined fluoroscopically and with serial spot roentgenograms. After swallowing three mouthfuls of fluid barium mixture rapidly, the patient was instructed to take a deep breath and hold it as long as possible. Observations were made in the frontal and oblique erect positions. In the early part of this study similar examinations were made in the recumbent positions as well, and thick barium paste also was utilized. Tabulations were made of the 100 patients varying in age from eighteen to seventy years. Thereafter, records only of those who showed changes of unusual interest were kept.

Forty per cent of the patients showed no gross delay in the passage of the barium mixture through the lower esophagus. However, when a deep inspiration was maintained there was a transient dilatation of the distal esophagus. No definite ampulla was formed, nor did the esophageal dilatation cause retroperistalsis or gross changes in the configuration of the esophagus. At times a momentary hesitation in the entrance of the barium into the stomach was noted immediately after the patient inhaled deeply.

In 35 per cent of the patients, the distal end of the esophagus above the diaphragm assumed a blunt or tapered appearance within a few seconds after deep inspiration. There was a delay of up to about five seconds in the entrance of barium into the stomach. The point of hesitation varied from 2 to 5 cm. above the diaphragm, and as recorded on spot roentgenograms the point was at the level of the eleventh and twelfth thoracic vertebrae.

Immediately after the supradiaphragmatic portion of the esophagus contracted, a dilatation of the esophagus appeared just above the point of change. It is assumed that the lowermost point of contraction indicates the site of the inferior esophageal sphincter and that the dilatation is the phrenic ampulla. Why so variable a phenomenon occurs with deep inspiration is a question of considerable interest.

The epiphrenic dilatation in this group of patients either was fusiform or ovoid. Retroperistaltic activity was observed pushing the barium mixture back into the middle third of the esophagus, while only a trickle entered the stomach. As the patient maintained inspiration, barium began to enter the esophagus below the lower esophageal sphincter in spurts of varying sizes. Often a fluid level would form in the dilated lower esophagus, and this could be seen descending as the barium entered the stomach through the now distended inferior esophageal sphincter. Considerable variation was noted at the point of delay. In some the tapered configuration appeared first, then the tapered tip became blunt or almost horizontal. In a period varying from one to about five seconds, barium entered the stomach while the inspiratory effort was maintained. During this time the caliber of the diffusely distended esophagus remained unchanged for a moment and then diminished as barium entered the stomach. During moments of retroperistalsis the lumen of the esophagus diminished in size. The transitory dilatation of the esophagus persisted to some degree even when part of the barium had entered the stomach, so that an air contrast type of roentgenogram was obtained. If the patient exhaled the column of barium dropped rapidly into the stomach.

In the remaining 25 per cent of patients, a similar but exaggerated phenomenon occurred. Instead of a diffuse widening of the lower esophagus, a spherical or ovoid dilatation became manifest during inspiration. This terminated either in a sharply pointed or almost circular inferior border. Retroperistalsis appeared fairly often at the moment of maximum distention. In some the barium trickled into the gastroesophageal vestibule while the circular dilatation persisted. Fluid levels appeared which descended with each pulsation of barium into the stomach. With relaxation of inspiration this dilatation vanished and the barium flowed into the stomach rapidly. It did not appear necessary for the esophagus to

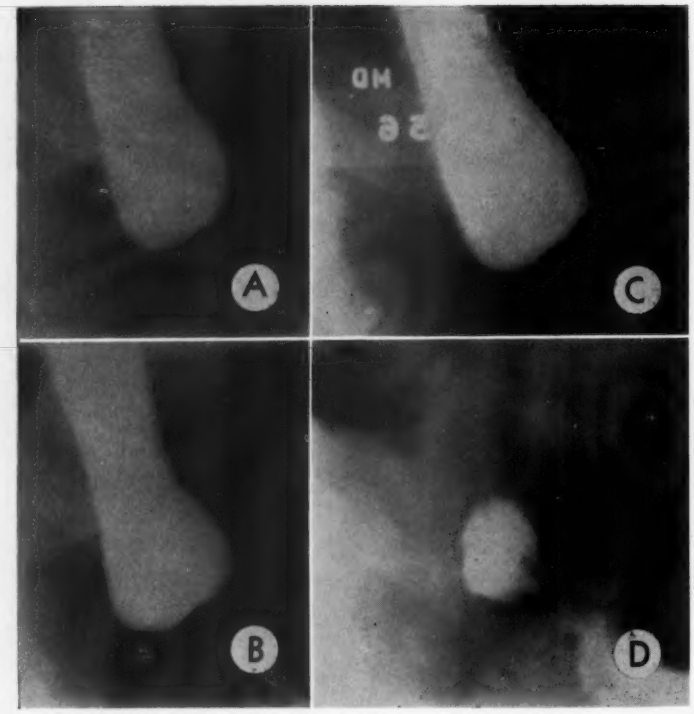

FIG. 3. Four serial erect spot roentgenograms made about two seconds apart. The first (*A*) was made immediately after the patient had swallowed three mouthfuls of liquid barium and then taken a deep breath *B* and *C* were taken while the deep inspiration was maintained. *D* was taken immediately after the patient had exhaled. Note the blunted configuration of the dilated distal end of the esophagus. In *D* the esophagus has emptied but a small amount of barium remains in the phrenic ampulla.

FIG. 4. Erect spot roentgenograms taken about four seconds after ingestion of liquid barium followed by a deep breath. A phrenic ampulla is formed. Above this tertiary contraction waves are seen on the anterior aspect of the esophagus (*A*). While respiration was maintained the esophagus began to empty, but the phrenic ampulla persisted as the esophagus above it narrowed (*B*).

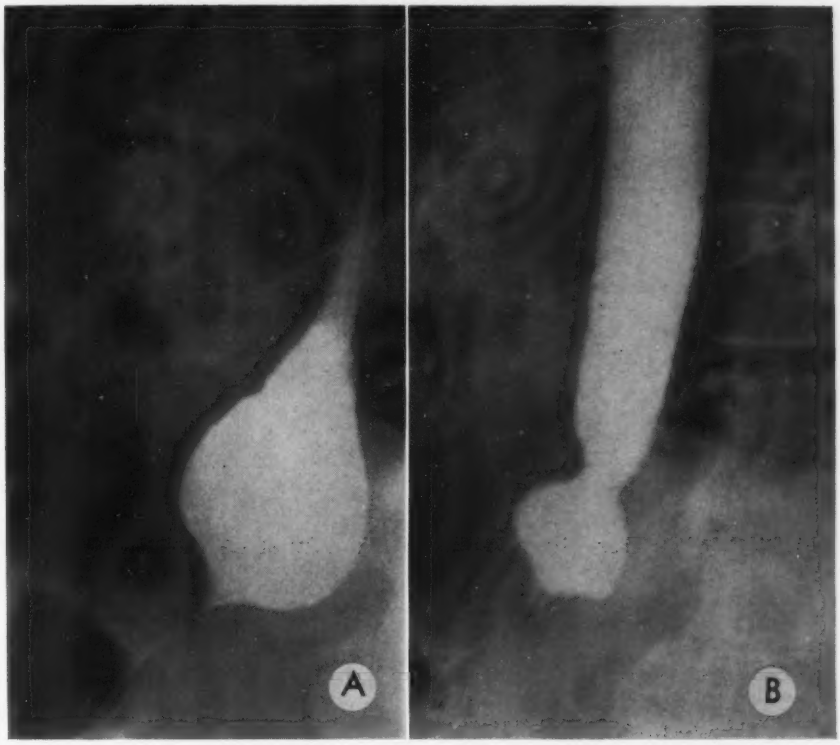

Fig. 5. Erect spot roentgenograms showing phrenic ampulla formation immediately after deep inspiration (*A*). With inspiration maintained, retroperistalsis pushes the barium back into the esophagus, diminishing the size of the ampulla (*B*). At this moment a small trickle of barium enters the stomach. Note the narrowing of the esophagus at the proximal end of the ampulla in *B*.

be distended with fluid for the ampulla to form, inasmuch as this phenomenon took place while the phrenic ampulla was partly filled with gas and fluid.

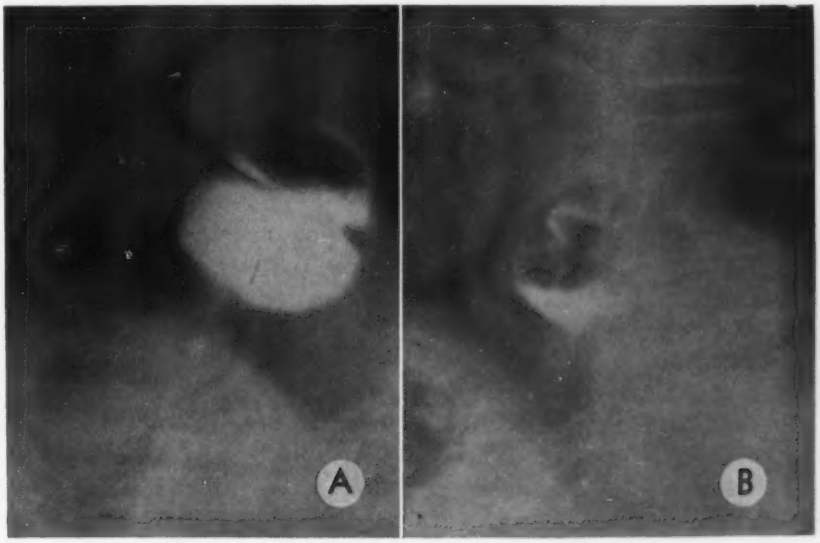

Fig. 6. Contraction ring in midportion of phrenic ampulla (*A*). Note the air-fluid level in the ampulla. The ring is partly maintained after relaxation of the ampulla (*B*).

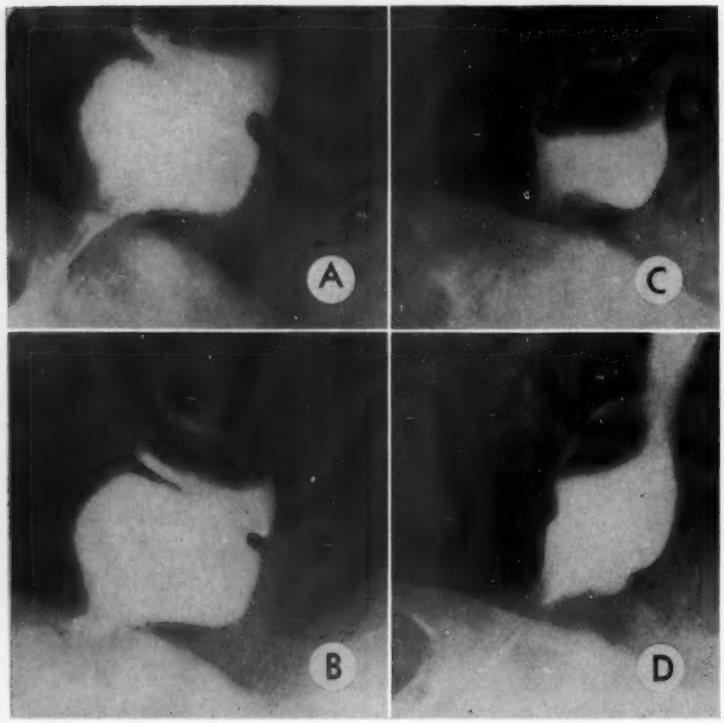

Fig. 7. (*A*, *B*, *C* and *D*). Same patient as Figure 6 one day later. Four erect spot roentgenograms at approximately two second intervals. The contraction ring in the phrenic ampulla can again be seen. The ring varies considerably in appearance during this sequence.

At times the similarity in appearance between a hiatal hernia and a phrenic ampulla was striking, particularly if the stomach was examined with the patient recumbent after swallowing the barium and taking a deep breath.

In 5 patients horizontal rings appeared in the midportion of the phrenic ampulla. These corresponded to those described by Ingelfinger and Kramer,[3] and Schatzki and Gary.[7] Unlike some of theirs, none of our patients had difficulty in swallowing. Ingelfinger and Kramer regarded the ring formation as an active motor phenomenon. Three of their 6 cases showed no visible changes on esophagoscopy. Schatzki and Gary considered the ring a passive structure, fairly constant in position but variable in diameter. They noted the ring only when the esophagus was distended, and observed that it could not be seen in the upright position except in rare instances. This does not correspond with the present observations. Since the ring is well above the diaphragm and the inferior esophageal sphincter, it is unlikely that it is influenced by the muscular action of the diaphragm or that it necessarily reflects the line of junction of the esophageal and gastric mucous membrane.

SUMMARY

Erect fluoroscopic and spot film roentgenographic examination of the lower esophagus immediately after ingestion of liquid barium followed by a sustained deep inspiration discloses a transient, variable dilatation in the lower esophagus. A fluid level may form here and active retroperistalsis may appear. No changes in sensation or taste were noted during this occurrence. This dilatation is considered to be the phrenic ampulla. Horizontal bands were observed in 5 patients in this structure. Neither excessive filling nor recumbency was necessary for the production of this appear-

ance. It is believed that this is a neuromuscular change in the esophagus incident to the effects of deep inspiration rather than one related to muscular action of the diaphragm.

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MILK OF CALCIUM BILE IN THE COMMON DUCT*

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"MILK of calcium bile" is a term used to describe radiopaque deposits encountered within the gallbladder. It consists almost entirely of calcium carbonate. The demonstration of this material in the gallbladder is common, but in the common duct is quite rare. A review of the American literature disclosed 1 case, reported by Cohen[2] in 1955. The purpose of this paper is to review the literature, describe the roentgenologic criteria for diagnosis, discuss the etiology of the formation of milk of calcium bile, and to present two cases.

The first report of milk of calcium bile was made by Churchman[1] in 1911. He described a putty-like material in the gallbladder which contained soaps of calcium salts on chemical analysis. The term milk of calcium bile was coined by Volkmann[7] who in 1926 reported 2 cases in which the gallbladder contained a white opaque fluid instead of bile. In 1933, Phemister *et al.*[6] reported 7 cases with calcium carbonate deposits in the gallbladder. The cystic duct was obstructed in each case. In 1935, Kornblum and Hall[4] added 5 cases, and in 1942, McCall and Tuggle[5] reported 15 cases.

Milk of calcium bile is essentially calcium carbonate. Johnston *et al.*[3] described this substance as occurring in the gallbladder in four different forms: (1) milky fluid, (2) streaks of opaque material in translucent gelatinous mass, (3) putty-like or pasty material, and (4) pure calcium carbonate stone. The formation of calcium bile and of carbonate gallstones is probably closely related. Most observers believe that one prerequisite is block of the cystic duct. This may occur with a gallstone, stenosis due to cancer, or intrinsic and extrinsic inflammatory disease. Wilkie[8] by ligation of the cystic duct in rabbits produced calcium stones when cholecystitis was present. When the cystic duct was patent, only cholesterin stones were formed. He concluded that the cystic duct must be occluded before certain changes occur in the physiology which lead to mucosal alterations in the wall of that organ. He postulated that the calcium was excreted by the gallbladder; however, there is no agreement upon the origin of the calcium. Phemister *et al.*[6] believed that it was excreted by the gallbladder wall because he was able to demonstrate the deposition of a rim of calcium only on the gallbladder side of stones in the cystic duct. Others believe that it comes from the bile because the calcium content in the gallbladder bile is increased in the presence of inflammation. The normal acidifying function of the gallbladder is interfered with by infection, and calcium precipitation occurs. There is contradictory evidence regarding the origin of milk of calcium bile and the problem is not settled.

Roentgenologically, milk of calcium bile appears as a dense, amorphous material within the gallbladder, resembling the image seen following the administration of gallbladder contrast medium. In fact, one of the criteria for its diagnosis is that the administration of oral cholecystographic contrast material does not alter the appearance of the opaque gallbladder seen on the plain roentgenogram. The diagnosis is further strengthened by the presence of a stone in the expected position of the cystic duct. Also, the administration of a fatty meal will cause no change in the appearance of the gallbladder. It may be confused with a haustral marking in the colon or a renal calculus. Oblique and lateral projections of the right upper abdomen will help to differentiate these abnormalities from the opaque bile shadow. The ease of diagnosis of this condition on a plain roentgenogram is one of our reasons for making

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this study routine prior to cholecystography.

REPORT OF CASES

Case 1. A sixty-one year old white female was admitted to the hospital complaining of jaundice and pain in the right upper quadrant of the abdomen. The pain began six days before admission and was referred to the back and right flank. The patient was not jaundiced in the past.

Past History. There were two attacks of severe pain prior to the present illness. There was also a long history of indigestion. Eighteen months before admission, the patient had cholecystography at another hospital. This revealed an abnormally functioning gallbladder but no evidence of stones or opaque material within the gallbladder.

Physical Examination. The patient was an obese white female in acute distress. There was marked tenderness and rigidity in the upper right quadrant of the abdomen. The sclerae and skin were moderately icteric. The physical findings were otherwise normal.

Fig. 1. A plain roentgenogram of the abdomen showing milk of calcium bile in the gallbladder and common duct with an opaque calculus at the head of the opaque bile column.

Fig. 2. Artist's drawing of the roentgenogram reproduced in Figure 1.

Roentgen Findings. A plain roentgenogram of the abdomen showed opaque material within the gallbladder. Intermixed were many non-opaque densities. The gallbladder seemed smaller than normal. There was also an elongated column of opaque material of similar density on the medial aspect of the gallbladder in the expected position of the common duct. At the head of this column was an opaque stone, 1.2 cm. in diameter. The stone was at the estimated level of the ampulla of Vater (Fig. 1 and 2).

These findings indicated milk of calcium bile in the common duct and gallbladder with a stone in the distal end of the common duct and multiple calculi in the gallbladder.

Operative Findings. Laparotomy revealed the gallbladder to be small, contracted and thick walled. A few stones were palpated in the gallbladder. The gallbladder was removed. The head of the pancreas was normal. The common

Fig. 3. A plain roentgenogram of the abdomen showing milk of calcium bile in the gallbladder and common duct with two stones in the common duct.

duct was opened and three small stones, plus a putty-like material, were removed. A catheter was passed into the duodenum, a "T" tube was inserted into the common duct and the abdomen closed.

Pathologic Report. The gallbladder was 7.0 cm. long and 2.2 cm. in diameter. It was soft, pink and yellow with fatty deposits on the peritoneal surface. The wall was 0.3 to 0.6 cm. thick. The mucosa was thick, soft, yellow and fatty. The lumen contained a little viscid, greenish-yellow bile and a large amount of yellow muddy material. The three small stones removed from the common duct measured approximately 0.5 cm. in diameter. They were rough on the surface and yellow in color.

Hospital Course. This was uneventful and the patient was discharged in seventeen days.

Diagnosis. Cholecystitis with cholelithiasis.

Case II. A forty-one year old white female was admitted to the hospital complaining of severe, recurrent, right upper quadrant abdominal pain which had been present for the past seven days. The pain was stabbing and knife-like and was relieved by morphine sulfate. The patient was entirely well prior to the onset of present illness, except for vague epigastric pain following ingestion of fatty foods. This indigestion was not severe enough to cause her to seek medical advice.

Physical Examination. The patient was a well nourished white female in acute distress. The skin and sclerae were slightly icteric. The right upper quadrant of the abdomen was extremely tender to palpation and there was moderate muscle guarding. The other physical findings were normal.

Roentgen Findings. A plain roentgenogram of the abdomen showed opaque material in the gallbladder. There were small nonopaque shadows within the opaque substance. The gallbladder shadow was small. Medial to the gallbladder was a long column of opaque material similar in density to the gallbladder; this was in the expected position of the common duct. This material contained two large stones, 0.8 cm. in diameter. One of these was at the head of the opaque column in the lower portion

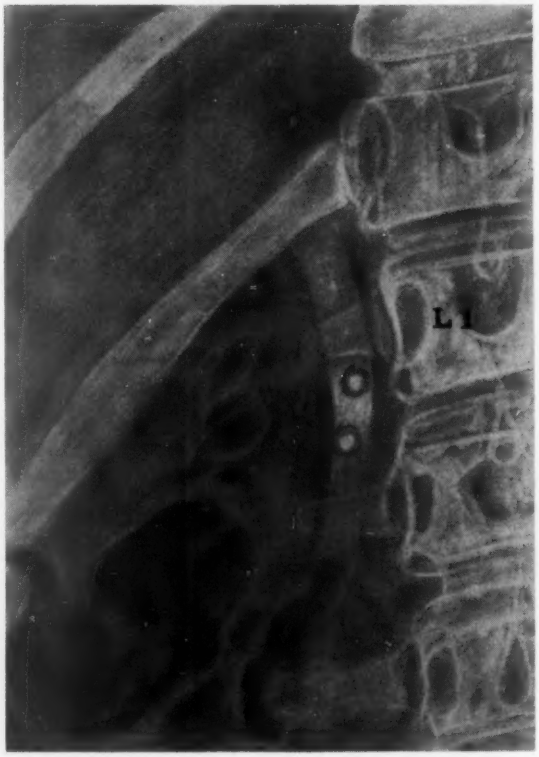

Fig. 4. Artist's drawing of the roentgenogram reproduced in Figure 3.

of the common duct; the other calculus was found just proximal to this level. These findings suggested stones in a dilated common duct and gallbladder with milk of calcium bile in both the common duct and gallbladder (Fig. 3 and 4).

Operative Findings. Laparotomy revealed the gallbladder to be dilated and edematous. The common duct and head of the pancreas were inflamed. The entire biliary tree was involved in a widespread inflammatory process. The surgeon felt it was unwise to excise the gallbladder and explore the common duct under these circumstances. A cholecystostomy was carried out. The mucosa of the gallbladder was necrotic throughout. There was a green thick sludge of almost putty consistency in the lumen of the gallbladder.

Hospital Course. Drainage through the catheter was maintained. The jaundice cleared. The patient was returned home for convalescence. A month later she was re-admitted for removal of the gallbladder and exploration of the common duct. By this time, one of the stones in the common duct and the milk of calcium bile had disappeared. The other stone remained in the common duct and was removed. The patient then had an uneventful recovery.

Diagnosis. Empyema of the gallbladder; calculi in the common duct; pancreatitis.

In the 2 cases reported here, opaque shadows of calcium density were found in the gallbladder and common duct on plain roentgenograms of the abdomen. In each case, an opaque calculus was seen at the head of the column of "limey bile" in the common duct. Both patients had a past history of intolerance to fatty foods as well as a recent acute attack of right upper quadrant pain which was associated with jaundice. This latter condition had not been present in either case prior to the onset of the acute biliary colic. Surgical exploration of the common duct in each case confirmed the presence of a calculus. One wonders if prior to the acute attack, the gallbladder contained the milk of calcium bile with the calculus being lodged in the cystic duct, then with the final illness, the "limey bile" and calculus were passed into the common duct, leaving a small amount behind in the gallbladder.

The 2 cases reported here are very similar to the case reported by Cohen.[2]

SUMMARY

1. Two surgically verified cases of milk of calcium bile in the common duct are presented.

2. The roentgenologic criteria for diagnosis of this condition are evaluated.

3. The etiology of the formation of milk of calcium bile is discussed.

4. The literature of this subject is reviewed.

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HIRSCHSPRUNG'S DISEASE*

THE ROENTGEN DIAGNOSIS IN INFANTS

By WILLIAM A. EVANS, M.D.,† *and* ROBERT WILLIS, M.D.
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THE pathogenesis of Hirschsprung's disease, that is an absence of the ganglion cells of the myenteric plexus in a segment of bowel as reported by Zuelzer and Wilson,[22] and Whitehouse and Kernohan[21] in 1948, is generally accepted. The principle of treatment, that is the removal of the aganglionic segment of bowel as proposed by Swenson and Bill[17] likewise in 1948, is also now generally accepted. Some technical details of the operation and its application in the younger age groups have yet to be worked out and generally established.[13,14] While the clinical and roentgen diagnosis, as described by Swenson, Neuhauser and Pickett[20] in 1949, is applicable to older infants and young children in typical cases, diagnostic criteria are less well established and recognized for the newborn and young infant. This is indicated by the development of the technique of rectal biopsy for diagnosis in problem cases by Swenson, Fisher, and MacMahon[18] in 1955, by the use of special physiologic aids to diagnosis in some quarters (Koop[10]), and by an impression that the true incidence and importance of the disease as a cause of death in young infants are not being generally recognized.

It is the purpose of this communication to review and extend an investigation of the roentgen diagnosis reported in 1954.[12] The present study is based on 24 additional cases. These cases with the 11 reported by Zuelzer and Wilson[22] in 1946 and 1948 and the 16 reported by McDonald and Evans[12] in 1954 make a total of 51, comprising the eperience with Hirschsprung's disease at The Children's Hospital of Michigan in recent years. Three related cases are also included in discussing the differential diagnosis (Cases XXV–XXVII).

In this group of 24 cases of Hirschsprung's disease are 20 males and 4 females, 18 of whom are white and 6 are Negroes. Histologic confirmation of the diagnosis was obtained in 19 cases. Nine of the group are dead with autopsies obtained in 7. The first barium enema examination was performed at less than one month of age in 14 cases, between one and six months in 4 cases, between six months and one year in 4 cases, and at over one year of age in 2 cases. Surgical procedures were carried out in all but 4 of the cases. These comprised laparotomy in 2 cases, a colostomy alone in 7 cases, a colostomy followed by a Swenson procedure in 4 cases, and a primary Swenson procedure in 7 cases. The junction of the ganglionic and aganglionic segments was estimated to be in the rectum in 1 case, at the rectosigmoid junction in 12 cases, in the sigmoid colon in 6 cases, in the descending colon in 2 cases, in the ileum in 1 case, and indeterminate in 2 cases.

THE AGANGLIONIC SEGMENT

The absence of ganglion cells of the myenteric plexus in the bowel commonly extends from the anus through the rectum to an area near the junction of the sigmoid colon and rectum. Swenson[15] reported in 1953 that in 47 per cent of the cases seen by him up to that time the bowel was aganglionic only below the pelvic peritoneal reflection. Extension into the sigmoid or descending colon is not rare and a few cases have been reported in which the entire colon and even a portion of the small bowel were aganglionic. In general, the aganglionic segment extends continuously for a varying distance above the anus. In very

* From The Children's Hospital of Michigan. Presented at the Fifty-seventh Annual Meeting of the American Roentgen Ray Society, Los Angeles, California, September 25–28, 1956.
† Deceased.

exceptional cases there may be an isolated zone in which there is an absence of ganglion cells. Three such cases have been mentioned by Bodian, Carter and Ward;[2] Keefer and Mokrohisky[8] found two zones of aganglionosis in 1 case; and Swenson[16] in 1955 reported the absence of ganglion cells extending from the anus in 150 cases with the exception of 1 case in which there was a cuff 4–6 cm. long in the lower rectum containing ganglion cells. In 115 cases reviewed by Bodian[3] in 1955 and in the 24 reported by Berman[1] in 1956, all were aganglionic to the anus. How short a segment of aganglionosis may exist and cause symptoms does not yet seem established. Certainly some segments may be so short as not to be definitely recognizable in the barium enema study and yet be productive of severe constipation as in Case XXIV.

The aganglionic segment of bowel was originally described by Swenson and Bill[17] as a "benign spastic lesion." Usually it is described as being of normal or less than normal caliber, but many observers have recognized that it is distensible. An aganglionic rectum may be distended by a Foley catheter or by a large barium enema but is characteristically empty of fecal masses. Rehbein and Wernicke[13] observed that the rectum may be more distensible than the aganglionic bowel immediately above it, thus giving a false impression of a short segment of aganglionosis. It is also recognized at operation and autopsy in advanced cases that the proximal portion of the aganglionic segment may become dilated by the attempted propulsion of fecal masses from the ganglionic bowel. Hence the level of disparity in caliber in the bowel may be somewhat below the level of the junction of the ganglionic and aganglionic segments. The aganglionic bowel exhibits small irregular uncoordinated peristaltic activity by manometric balloon studies and is the site of a functional obstruction attributable to faulty peristalsis or achalasia.

THE GANGLIONIC SEGMENT

The colon proximal to the aganglionic segment contains a normal number and distribution of ganglion cells except in some cases where there is a transitional zone of variable length containing a diminishing number of ganglion cells toward the totally aganglionic segment. In Hirschsprung's disease of long standing, the ganglionic bowel is dilated with an hypertrophied wall and often an ulcerated mucosa in response to chronic obstruction and retention of feces. The most marked dilatation and hypertrophy occur immediately above the obstruction, that is, in the descending portion of the sigmoid colon in the typical case where the aganglionosis extends from the anus to the rectosigmoid junction. The dilatation and hypertrophy extend more proximally with increasing duration of the obstruction. These manifestations are not present in the newborn or in the first few days of life. In 3 cases reported by Ehrenpreis[6] in 1945 they were not recognized until three to six weeks of age in 2 cases and not until the age of three and one-half months in 1 case. The pathologic changes in the ganglionic segment are reversible, and this takes place following colostomy or removal of the aganglionic segment and may occur during the latent symptom free intervals of the disease (Burnard[4]) or after diligent and successful efforts to evacuate the bowel by catharsis and enemas.

The disparity in caliber between the ganglionic and aganglionic segments is the basis for the roentgen diagnosis of Hirschsprung's disease as described by Swenson, Neuhauser and Pickett[20] and many others since. It is recognized, however, that a disparity in caliber is not present in all newborns and is not recognizable or present to only a slight or doubtful degree in many young infants. McDonald and Evans[12] were impressed that the disparity in caliber is often more readily recognized in film studies made 24 and 48 hours following a barium enema and this is confirmed in the present series (Case IV, Fig. 1; Case VI, Fig. 3; Case XII, Fig. 6; Case XIII, Fig. 7). These findings have also been recently confirmed by Berman[1] who found that the examination by barium enema was not diagnostic of Hirschsprung's disease in 4 of 19 cases

studied in the first month of life. In Case v (Fig. 2) a disparity in caliber was recognized in a barium enema examination performed at five days of age indicating the junction of the ganglionic and aganglionic segments to be near the splenic flexure and this was confirmed at autopsy. In Case VIII (Fig. 4) a disparity in caliber was observed in the sigmoid colon at twenty-four hours and more clearly at forty-eight hours following a barium enema administered at two days of age with confirmation obtained from the surgical specimen at two and one-half years of age. In Case XV a disparity in caliber was suspected in the barium enema performed at three days of age and later confirmed. In Case XVIII (Fig. 8) a clear disparity in caliber was observed at forty-two hours following a barium enema administered at three days of age and confirmed at autopsy. In Case XIX (Fig. 9) a well marked caliber disparity was demonstrated in the barium enema examination performed at fifteen days of age.

STASIS

Ehrenpreis[6] in 1945 recognized that the primary manifestation of Hirschsprung's disease was a failure of the colon to empty its content and that this could be recognized in the newborn period by observing a poor evacuation of the barium enema in contrast to the forceful rapid evacuation of the barium enema in normal infants. The value of observing infants 24 to 48 hours or longer following the administration of a barium enema was emphasized by McDonald and Evans[12] in 1954, by Klein and Scarborough[9] in 1954 and by Berman[1] in 1956 for the early diagnosis of Hirschsprung's disease. In the present series of 24 cases, a significant and often marked degree of stasis was observed in all cases although not in all examinations. Stasis was not recognized or was regarded as questionable or absent in 4 of the initial examinations in the 24 cases. Stasis was demonstrated before a recognizable disparity in caliber of the segments in 5 cases. Stasis occurs in both the ganglionic and aganglionic segments but is more marked in the ganglionic segment. Stasis in a totally aganglionic colon was reported by Swenson and Fisher[19] and by Berman[1]. An almost complete colonic stasis for eleven days was present in a similar instance (Case X, Fig. 5) in this series. Colonic stasis was demonstrated but not recognized as being due to Hirschsprung's disease in 3 cases in this series (Case VII, X and XXIV). In Case X the whole colon and lower ileum were aganglionic, in Case VII the history was inadequate or misleading with more clinically prominent incidental complications, and in Case XXIV stasis was attributed to simple chronic constipation in the absence of a demonstrable disparity in caliber of the segments in a four year old child.

DIFFERENTIAL DIAGNOSIS

A disparity in caliber of segments in the lower bowel may suggest a rectal web, stenosis, or stricture (rectal malformation Type I according to the classification of Ladd and Gross) as mentioned by Swenson, Neuhauser, and Pickett.[20] Actually, such a lesion would seem to be very rare and the appearance of such a lesion as in Case II would now seem to be more probably due to Hirschsprung's disease. Obstructing intraluminal organic masses (excepting intussusception) must also be extremely rare in infants and such an appearance as in Case IV would seem to be more probably due to fecal masses incident to the fecal stasis of Hirschsprung's disease.

The clinical manifestations of Hirschsprung's disease in the newborn may be simulated by atresia or stenosis in the small bowel, colon, or rectum, by meconium ileus and by the meconium plug syndrome (Burnard,[4] Ehrenpreis,[7] Lee,[11] and Clatworthy, Howard, and Lloyd[5]). In such cases we have observed a prompt and fairly complete evacuation of the colon after barium enema examination in contrast to the prolonged stasis in the colon of Hirschsprung's disease. Thus, the evacuation of the colon is not dependent on a *vis a tergo* and occurs in the presence of more proximal

obstructing lesions.

In the meconium ileus of fibrocystic disease of the pancreas, a bowel obstruction, usually complete, is produced in the newborn by a meconium of a thick viscid consistency. This is usually present in the lower ileum, thus producing signs of ileal obstruction. Here, as in ileal atresia, the barium enema can be introduced without too much difficulty and often rapidly into a small empty virginal colon. Occasionally, the meconium mass will extend into the proximal colon in meconium ileus, thus obstructing the retrograde flow of the barium enema, while in ileal atresia the enema may enter the terminal ileum to a point near the area of atresia. This differential point seems to have some statistical validity in comparing our cases of ileal atresia and meconium ileus but has not been of practical value in the individual case. However, in either case, an evacuation of the colon does occur distal to the area of obstruction (Case XXVI, Fig. 11).

The meconium plug syndrome, distinct from the meconium ileus of fibrocystic disease of the pancreas, seems to be a rare entity in its severe intractable form but probably not uncommon in milder forms. This disorder seems to be due to an abnormal consistency of the meconium rather than to any intrinsic anatomic abnormality of the bowel or to any primary neuromuscular dysfunction. In most instances the plug will occur somewhere in the distal colon and will be released without too much difficulty by enemas. In severe cases (Case XXVII, Fig. 12) the plug may be in the proximal colon or ileum; simple measures are ineffectual and ileostomy or colostomy may be required. There is some predilection for the disorder in prematures (Bodian[3]) and some prematures have been observed with inspissated fecal content of the small intestine producing a fatal small bowel obstruction. In instances of the meconium plug syndrome where the plug has not been released by the barium enema or subsequent therapeutic enemas and where the barium has become mixed with the meconium, a stasis of this barium would be anticipated.

The value of a sign depends not only on the frequency of its occurrence in the given situation but also on its specificity. How specific is colonic stasis for the diagnosis of Hirschsprung's disease? In our experience it has a high degree of specificity in the newborn and young infant. An exception may be assumed in some forms of duplication of the colon as was assumed in Case XXV (Fig. 10). This case proved to be a blind loop syndrome with an exceptionally long blind loop formed by the greater portion of the ileum following an inadvertent jejunocolostomy. The blind loop syndrome, thus, is another possible basis for abnormal stasis in the bowel although this will usually be recognized as occurring in a small segment of the small bowel following an entero-enterostomy. In simple chronic constipation, a prompt and fairly complete evacuation of the barium enema is usually observed. In some cases colonic stasis following a barium enema may be observed with the greater accumulation of barium in a dilated rectum. This situation does not usually occur before two or three years of age (Swenson[15]) and has not caused serious difficulty in differentiation from Hirschsprung's disease except where there is a very short aganglionic segment above the anus as in Case XXIV.

The roentgen diagnosis of Hirschsprung's disease is an exercise in pathologic physiology. This implies that there will be many variables in the manifestations from time to time in the same case and in different cases and that the diagnosis will be made with variable degrees of certainty and uncertainty. In this situation the rectal biopsy as developed by Swenson and coworkers[18] and use of biopsies at laparotomy represent a most important and useful contribution to diagnosis.

REPORT OF CASES

Case 1 (J.H., CH53094). This three day old Negro male infant was admitted with a history of increasing abdominal distention and vomiting of thirty-six hours' duration and no bowel

movements since birth. Pregnancy and delivery were uneventul with a birth weight of 7 pounds, 12 ounces. Physical examination revealed a markedly distended abdomen and rectal examination allowed admission of the tip of the little finger. A rectal thermometer was introduced per anum but met resistance, and when pressure was applied a "thin rectal membrane was ruptured, following which a copious amount of meconium stool was passed." Barium enema study at three days of age was considered normal, but the evacuation of barium from the colon was not followed. The patient was discharged at seven days of age, and was readmitted again at three weeks of age because of abdominal distention, constipation and vomiting. No cause was found and the patient responded to medical treatment consisting of enemas and was discharged on the third hospital day. The child was followed as an out-patient until the age of four years with the complaint of chronic constipation requiring enemas for relief. At this time the child was readmitted to the hospital because of abdominal distention, chronic constipation, and failure to gain weight. Barium enema examination at this time revealed a marked dilatation of the sigmoid colon with a caliber disparity between the sigmoid colon and rectum and barium was still observed in the colon three weeks later. The patient underwent a Swenson type operation with resection of the colon from the mid-sigmoid to the anus. Pathologic examination of the surgical specimen revealed the distal 6 cm. of colon to be aganglionic. Subsequently the patient has gained weight with no recurrence of the previous symptoms.

Case II (J.B., CH58337). This five month old white male infant was admitted to The Children's Hospital of Michigan with the history of constipation since birth requiring enemas and castor oil to promote evacuation of the colon. The pregnancy and labor were uneventful with a spontaneous delivery. Physical examination revealed a markedly enlarged distended abdomen. Barium enema examination demonstrated an enormous distention of the descending sigmoid colon with a diminishing caliber in the rectosigmoid area and rectum. A marked stasis of barium was observed in the sigmoid colon at thirty minutes, six hours and forty-eight hours. Mecholyl bromide was administered without appreciable effect. The hospital course was relatively uneventful and the patient was discharged with the expectation of having a rectal stricture dilated by a proctologist. The infant continued to have constipation requiring frequent enemas. Because symptoms were controlled by mild laxatives and enemas, a definitive surgical procedure was not attempted until five years of age when the patient was admitted to Boston Floating Hospital. A sigmoidoproctectomy was performed revealing the distal sigmoid colon and rectum to be aganglionic. The patient was last seen at six years of age, and although he has occasional spontaneous bowel movements, intermittent diarrhea and irregular bowel habits have been troublesome.

Case III (P.C. CH67838). This two day old white male infant was transferred to The Children's Hospital of Michigan with the history of vomiting brown stained material for a period of twenty-four hours. The infant was delivered spontaneously following an uneventful pregnancy and labor. The birth weight was 7 pounds, 14 ounces. Physical examination revealed a distended tympanitic abdomen. A Levine tube was passed and continuous suction was instigated with complete relief of symptoms. At four days of age the patient was placed on oral feedings which were well tolerated and the infant was subsequently discharged. The infant was seen in the out-patient clinic on several occasions and always with a large protuberant abdomen. At two months of age constipation developed which was relieved by the use of frequent enemas and suppositories. A barium enema examination at two and one-half months of age revealed no caliber disparity, but slow evacuation of the colon was noted particularly in the descending and sigmoid colon. At ten months of age the patient was re-admitted because of intermittent constipation and diarrhea for two weeks. Physical examination again revealed a distended tympanitic abdomen. Barium enema examination at ten months of age showed a disparity in caliber between the rectum and the more proximal colon. Slow evacuation was again noted and at four hours a large amount of barium remained in the sigmoid colon contrasting with the small caliber of the rectum. The findings were considered to be indicative of obstruction at the rectosigmoid junction either on a neurogenic or organic basis. The patient did well on a medical management and was subsequently discharged. At two years of age

the patient was admitted to another hospital where he underwent a Swenson type operation with resection of the distal 14 cm. of colon. Pathologic examination of the surgical specimen was reported as an "abundance" of ganglion cells in the proximal portion of the specimen, but an absence of ganglion cells in the distal portion of the specimen. Following the surgery the patient developed a recurrence of symptoms, and barium enema examination at another hospital reportedly revealed a caliber disparity with the distal narrowed segment approximately 4 cm. long indicating that the resection of aganglionic bowel had been incomplete. The patient was still having severe constipation at four years of age.

Case IV (D.M., CH91138). This eighteen day old white male infant was admitted with a history of progressive constipation, intermittent vomiting and weight loss since birth. The pregnancy and labor were uneventful and the infant was delivered spontaneously with a birth weight of 6 pounds, 6 ounces. Physical examination revealed a distended, tympanitic abdomen. Barium enema examination at three weeks of age demonstrated a "polyp" at the rectosigmoid junction apparently causing some obstruction and a slow emptying of the colon in the thirty minute, six hour and twenty-four hour studies. There was still stasis of barium in the colon five days later and the possibility of Hirschsprung's disease was entertained. Proctoscopic examination revealed a rectal "stricture" which was dilated on several occasions. The patient began passing normal stools and was subsequently discharged. At two months of age the patient again developed constipation and barium enema examination at four and one-half months of age revealed a disparity in caliber between the descending and sigmoid portions of the colon. These findings were considered indicative of Hirschsprung's disease, although most of the barium was evacuated in one hour. The patient was last seen at three and one-half years of age and required frequent enemas and suppositories for evacuation of the colon.

Case V (J.A., CH96132). This two day old white male infant was transferred to The Children's Hospital of Michigan with a history of bile stained vomiting for one day. The pregnancy and delivery were described as uneventful, and the birth weight was 8 pounds, 2 ounces. Physical examination revealed a distended, tympanitic abdomen, but no masses were palpable. Roentgen examination of the abdomen in the supine and upright positions disclosed marked gaseous and liquid distention of the small bowel. An exploratory laparotomy was performed and a band was found to extend from the root of the mesentery across the transverse colon causing a high degree of colonic obstruction. This band was lysed and the abdomen closed with no other cause for intestinal obstruction being noted. The infant continued to vomit, and at five days of age barium enema examination revealed a caliber disparity between the transverse and descending colon with abnormal colonic stasis of barium at one day, three days, and seven days. The findings were considered indicative of Hirschsprung's disease with a long aganglionic segment extending from the anus to the splenic flexure. At fourteen days of age a transverse colostomy was performed following which the infant showed some improvement. During the second postoperative week, the infant suddenly became dehydrated and a high jejunal fistula was noted. The electrolyte balance was controlled by intravenous fluids, but at three months of age a marked electrolyte imbalance occurred and the infant expired. Postmortem examination revealed an aganglionic segment extending from the anus to the splenic flexure involving 31 cm. of the colon. A generalized peritonitis and jejunal fistula were regarded as the direct causes of death.

Case VI (J.R., CH102600). This two week old white male infant was admitted with a history of vomiting following feedings and chronic progressive constipation since birth. The infant was born spontaneously weighing 7 pounds, 5 ounces, and the prenatal history was considered normal. Physical examination revealed a marked abdominal distention with tympany to percussion and absent bowel sounds. Barium enema examination demonstrated a disparity in caliber between the sigmoid colon and rectum with stasis at four hours. The findings were considered diagnostic of Hirschsprung's disease. Following this study, a sigmoid colostomy was performed at fifteen days of age. Twenty-four hours following surgery the patient developed a thrombocytopenic purpura considered to be on an allergic basis, but although attempts were made to replace the blood platelets a progressive downhill course ensued and the infant ex-

FIG. 1. Case IV. Typical findings in Hirschsprung's disease obtained by the barium enema examination in an infant three weeks of age (*A*). The marked stasis in the colon for five days is to be noted and the disparity in caliber of the ganglionic and aganglionic segments which is not evident immediately and which is more marked at five days (*D*) than at one day (*B* and *C*).

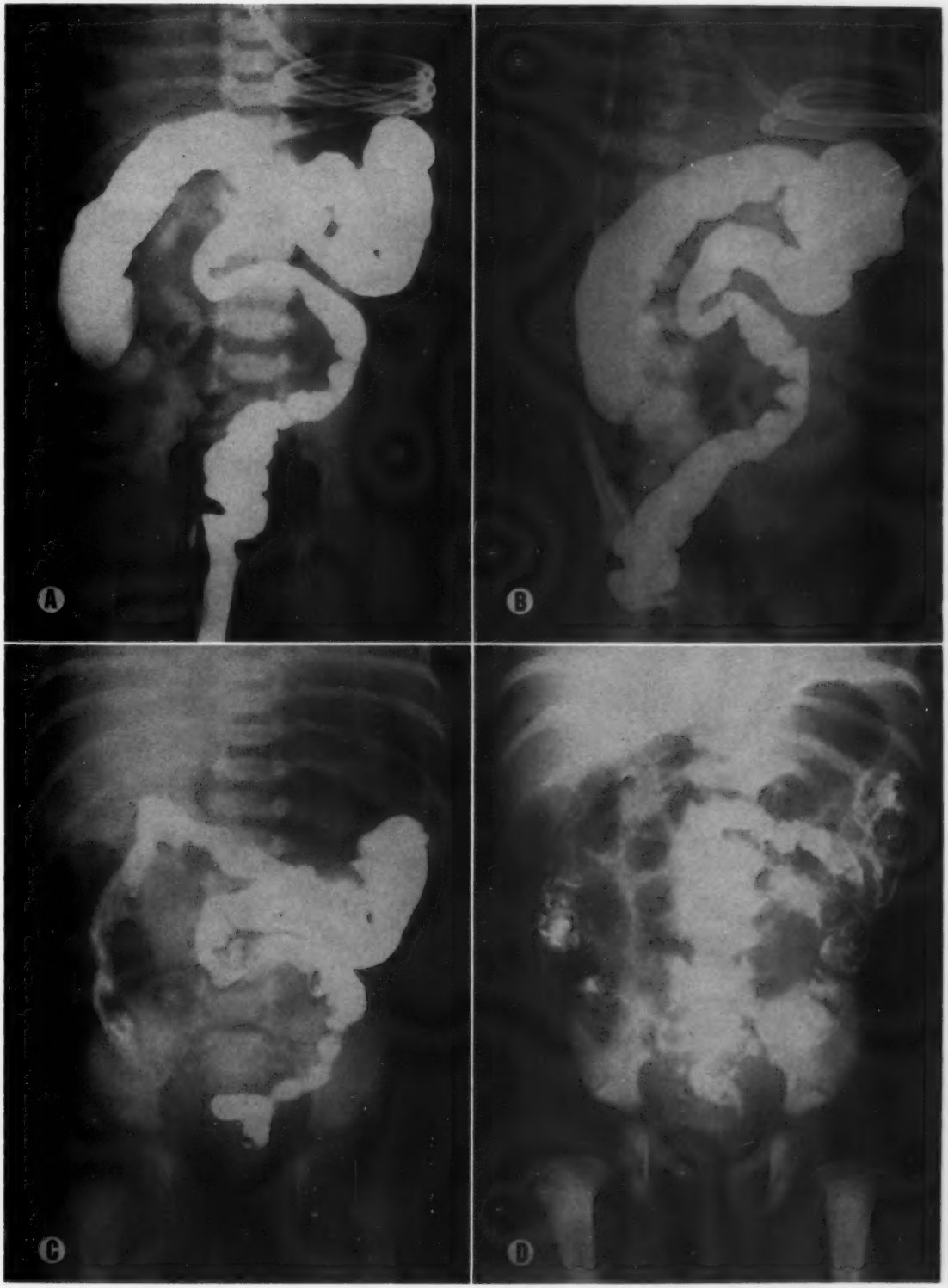

Fig. 2. Case v. A rather long aganglionic segment demonstrated by barium enema examination at five days of age (*A* and *B*) with an abnormal stasis of barium in both the ganglionic and aganglionic segments three days (*C*) and seven days (*D*) later.

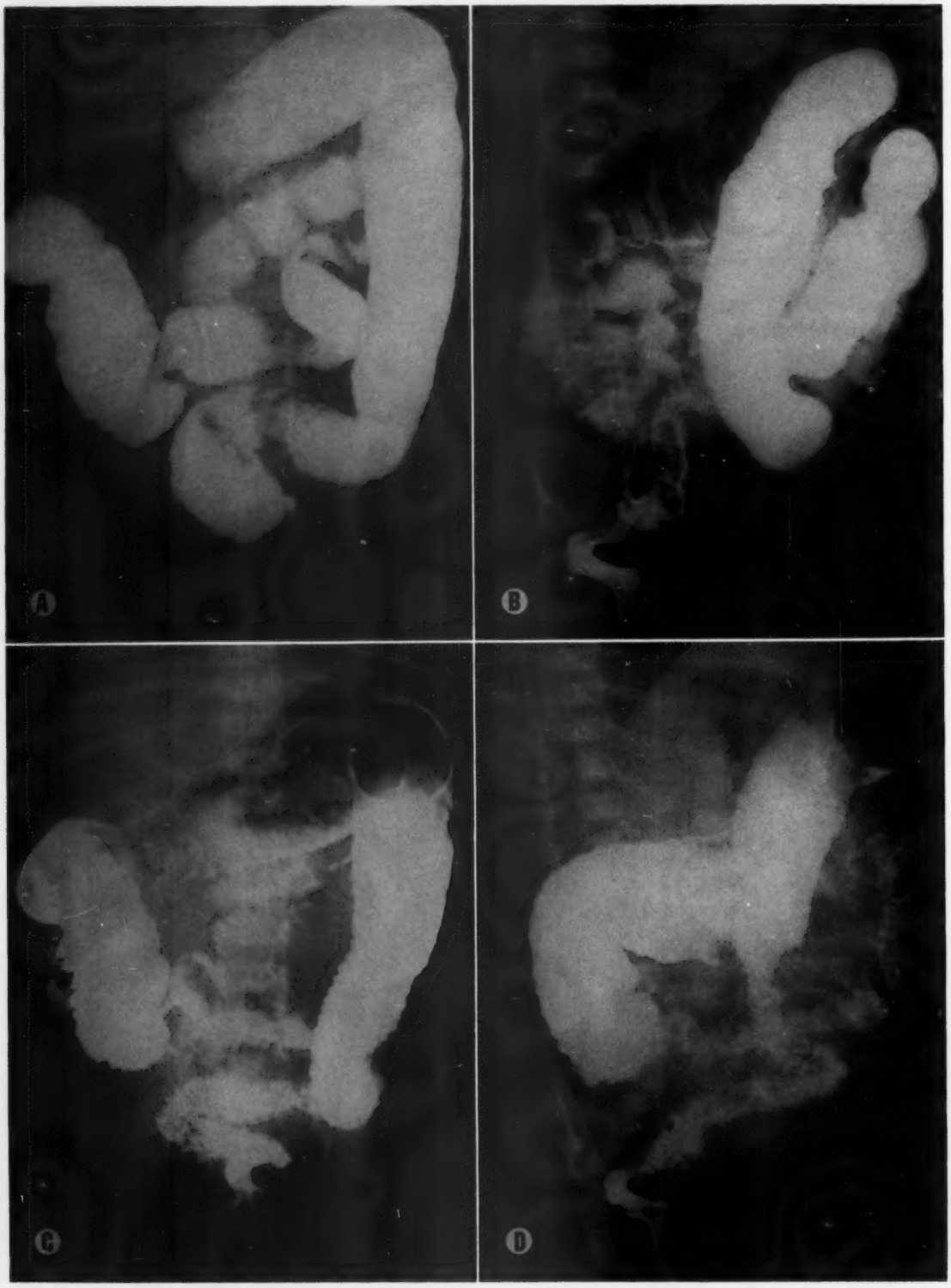

FIG. 3. Case VI. An aganglionosis demonstrated by barium enema examination at two weeks of age (*A* and *B*) with stasis and caliber disparity evident at four hours (*C* and *D*).

pired on the thirteenth hospital day. Postmortem examination revealed the distal 14 cm. of colon to be aganglionic. Death was attributed to an overwhelming staphylococcic septicemia.

Case vii (M.D.W., CH104415). This fourteen month old white female infant was transferred to The Children's Hospital of Michigan with a history of chronic intermittent constipation since birth relieved by enemas and suppositories. Three weeks prior to admission the infant developed vomiting, diarrhea and fever which were treated by antibiotics. These symptoms subsided but the development of progressive weight loss and severe constipation brought about hospitalization. The patient was studied at another hospital, but because surgery was contemplated she was transferred to this institution. The past history revealed a normal pregnancy and delivery with a birth weight of 7 pounds, 13 ounces. Physical examination revealed a chronically ill, poorly nourished female infant. The abdomen was soft and there were no palpable masses. A barium enema examination showed normal filling of the colon and no caliber disparity or obstruction was noted. Abnormal stasis of barium was found in a dilated terminal ileum, descending and sigmoid colon at one hour, three hours, five hours, twenty-three hours and forty-eight hours. The findings suggested an extrinsic obstruction to the terminal ileum. The patient underwent surgery on the sixth hospital day, and an omental band obstructing the terminal ileum was lysed. A retrocecal appendiceal abscess was also noted but appeared to be well localized and surgical intervention was felt to be contraindicated at that time. Following surgery the abdomen became distended and the patient developed marked nausea, vomiting and temperature elevation. The patient's condition deteriorated rapidly and on the sixth postoperative day she died. Postmorten examination revealed a retrocecal appendiceal abscess with partial ileocecal valve obstruction and dilatation of the terminal ileum. The walls of the colon appeared thickened and several microscopic sections of the colon revealed absence of ganglion cells although ganglion cells were demonstrated in the cecum.

Case viii (D.B., CH107563). This two day old white male infant was admitted because of abdominal distention, bile stained vomitus and failure to have a bowel movement since birth. The pregnancy and labor were uneventful with a spontaneous delivery of an infant weighing 7 pounds, 1 ounce. Physical examination revealed a massive abdominal distention with absent bowel sounds. At two days of age barium enema examination showed abnormal stasis of barium at two, four, twenty-four and forty-eight hours with a disparity in caliber demonstrated in the later studies between the descending and proximal sigmoid colon and the lower sigmoid colon and rectum. A diagnosis of Hirschsprung's disease was made with the aganglionosis extending from the anus into the lower sigmoid colon. Conservative therapy was tried but on the eighth day of life the abdomen became distended, and a sigmoid colostomy was performed. At fourteen months of age the patient was re-admitted with a diagnosis of "nephrosis" which was treated by a medical regimen with subsequent recovery and discharge. A normal intravenous pyelographic study was obtained and subsequent events indicated that the previous diagnosis of nephrosis was untenable. At two and one-half years of age a Swenson type operation was performed with removal of a segment of distal colon. The specimen was approximately 35 cm. in length with the distal 8 cm. contracted and aganglionic.

Case ix (K.R., CH108359). This four day old Negro male infant was transferred from another hospital with a history of failure to pass a stool since birth. The infant was born following a full term pregnancy and normal delivery, weighing 5 pounds, 11 ounces. Physical examination revealed mongoloid facies and the abdomen was distended. Barium enema examination at five days of age showed a high position of the cecum, but no caliber disparity or colonic obstruction. Stasis of barium in the colon was noted at eighteen hours and forty-two hours and this finding was considered indicative of Hirschsprung's disease. At six days of age the infant began to pass normal-colored stools and was discharged at thirteen days of age. The infant was re-admitted at six weeks of age weighing 5 pounds, 1 ounce with diarrhea of one week's duration. Physical examination revealed a soft systolic murmur over the precordium and marked abdominal distention. He was treated with intravenous fluids and plasma, but expired shortly after admission. Postmortem examination revealed a chronic hepatitis of undetermined etiology and a marked enteritis of the small bowel and proximal colon. Unfortunately,

FIG. 4. Case VIII. Hirschsprung's disease in an infant examined at two days of age (*A*) with stasis and caliber disparity demonstrated twenty-four hours (*B* and *C*) and forty-eight hours (*D*) later.

the microscopic sections of the colon were not recorded as to site of origin. However, in two sections no ganglion cells could be found, and it was assumed by the pathologist that these sections came from the sigmoid or descending colon.

CASE X (B.G.C., CH112239). This two day old Negro female infant was transferred to The Children's Hospital of Michigan with a history of bile stained vomitus, abdominal distention and failure to have a stool since birth. The pregnancy and delivery were uneventful with a birth weight of 6 pounds, 4 ounces. Physical examination revealed a distended, tympanitic abdomen with decreased bowel sounds. Barium

enema examination disclosed a marked gaseous distention of the small bowel indicating a low ileal obstruction, but the caliber and appearance of the colon were considered normal. A subsequent study of the abdomen at twenty-four hours revealed abnormal colonic stasis of barium. At three days of age a laparotomy was performed with decompression of the small bowel, but no obstruction was found. Roentgen examination of the abdomen at seven days, nine days, and eleven days following the barium enema revealed a persistent stasis of barium in the colon. The small bowel distention which was felt to represent a low ileal obstruction persisted. Because of this a second exploratory laparotomy was performed at twelve days of age. Multiple adhesions were noted in the right lower quadrant, but no definite small bowel obstruction was found. The small bowel was again decompressed and the adhesions lysed. Following surgery the infant's condition deteriorated rapidly and she expired at fifteen days of age. Postmortem examination revealed multiple pulmonary abscesses, hepatic necrosis and adrenal atrophy. Approximately 5 cm. of the terminal ileum and the entire colon were aganglionic.

Case xi (D.W., CH113242). This white male infant was first admitted at one month of age with a history of vomiting following feedings since birth and diarrhea of one day's duration. The infant was delivered from a breech position following a labor of thirty-six hours. At birth the child weighed 7 pounds, 4 ounces. Physical examination revealed only a slightly distended tympanitic abdomen. The patient was treated for diarrhea and discharged on the seventh hospital day. The infant did well for about two months then developed vomiting and constipation which led to re-admission at six months of age. Physical examination at this time revealed a distended tympanitic abdomen. Barium enema examination at six months of age showed an abnormal colonic stasis of barium at six, twenty-four and thirty-one hours and at four and nine days with a persistently dilated descending sigmoid loop and relatively small rectum. These findings were considered diagnostic of Hirschsprung's disease with the aganglionic segment extending from the anus to the rectosigmoid junction. The patient continued to eat poorly and a sigmoid colostomy was performed. The infant improved following surgery and began taking oral feedings without symptoms. Following discharge the infant did well for one month but again developed vomiting for which he was re-admitted at eight months of age. He was treated with antibiotics and irrigation of the colostomy following which he improved and was discharged. Because the patient continued to have vomiting and abdominal distention, he was re-admitted at nine months of age for a revision of the colostomy. Following this procedure, he improved and began taking oral feedings again. The patient, however, still appeared chronically ill and malnourished and at twenty-two months of age was re-admitted for a Swenson type operation. About 25 cm. of colon was removed and the descending colon anastomosed to the lower rectum about 4 cm. above the anus. Pathologic examination showed the lower portion of the resected colon to be aganglionic and the proximal dilated portion with a thickened wall and ulcerated mucosa to contain nests of ganglion cells. Following surgery, the patient developed a lobar pneumonia and severe ileus. On the seventh postoperative day roentgen examination of the abdomen revealed free air beneath the diaphragm. An exploratory laparotomy was performed which revealed an extensive plastic peritonitis with disruption of the anastomotic site. The patient expired shortly following surgery and no postmortem examination was performed.

Case xii (M.F., CH114552). This one day old Negro female infant was transferred from another hospital with a history of vomiting and abdominal distention. The delivery was described as difficult with a labor of twenty hours' duration. Physical examination revealed a moderately distended, tympanitic abdomen. On rectal examination a tight ring was noted just proximal to the internal sphincter. Barium enema study at five days of age disclosed no abnormality with "fairly satisfactory but not complete emptying of the colon" at one and six hours. Following discharge, the infant continued to have occasional vomiting and constipation. She was re-admitted to the hospital at five weeks of age and barium enema examination at six weeks of age revealed dilatation of the ascending and transverse colon with a gradual diminution in caliber of the descending and sigmoid colon. There was marked stasis of barium in the colon at seven, twenty-four and seventy-two hours. These findings were considered indicative of Hirschsprung's disease

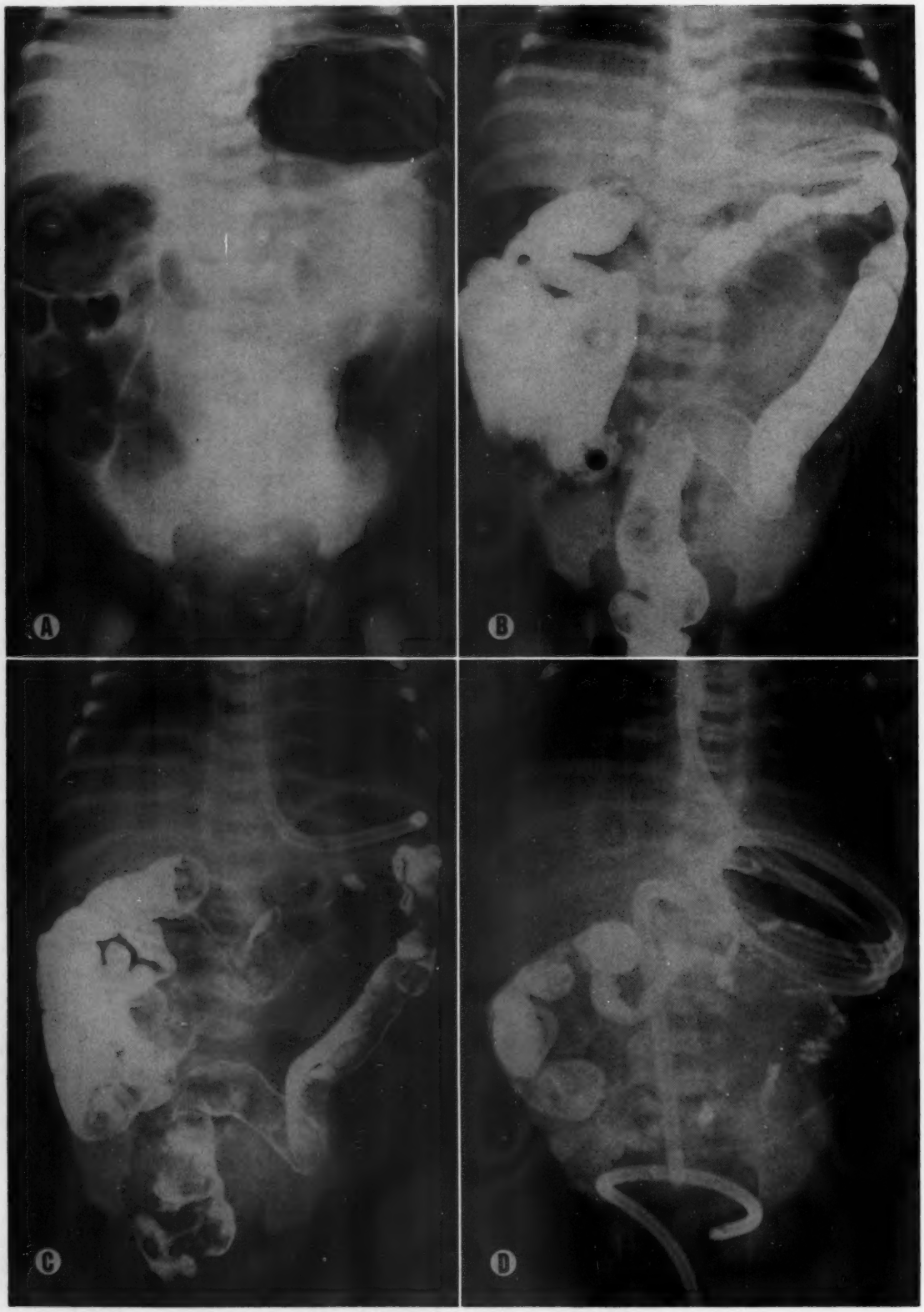

FIG. 5. Case x. Aganglionosis involving the entire colon and lower ileum demonstrated at two days of age (*A* and *B*) by barium enema study. Abnormal stasis of barium in the aganglionic colon was found one day (*C*) and eleven days (*D*) later.

Fig. 6. Case xii. Mild colonic stasis with no appreciable caliber disparity not recognized as Hirschsprung's disease by barium enema examination at five days of age (*A* and *B*). Slight caliber disparity and marked 24 hour stasis indicating Hirschsprung's disease in the barium enema examination at six weeks of age (*C* and *D*).

with a long aganglionic segment extending from the anus into the descending colon or splenic flexure. A transverse colostomy was performed at six weeks of age following which the patient improved and was discharged. The infant was re-admitted at five months of age with diarrhea and vomiting which was treated with antibiotics and intravenous fluids with subsequent

recovery. The patient was last seen at two years of age with no symptoms.

CASE XIII (H.B., CH119507). This seven day old white male infant was admitted because of bile stained vomitus, black stools and lethargy for a period of twenty-four hours. The pregnancy was uneventful with a normal delivery, and the birth weight was 7 pounds, 12 ounces. Physical examination revealed nothing of significance. Barium enema and barium meal examinations at thirteen days of age were considered normal. The infant recovered under medical management and was discharged at sixteen days of age. He was re-admitted at nine months of age with chronic constipation, at which time barium enema examination revealed a disparity in caliber between the descending and mid-sigmoid colon with abnormal colonic stasis of barium at five and twenty-four hours. These findings were considered diagnostic of Hirschsprung's disease. At fifteen months of age, the infant was re-admitted and at this time barium enema examination again revealed typical findings of Hirschsprung's disease with marked stasis at three, seventeen and thirty-eight hours and at five days and a disparity in caliber between the proximal and distal portions of the sigmoid colon. A Swenson type operation was performed with resection of the distal 21 cm. of colon from the mid-sigmoid to the mucocutaneous junction of the anus. Pathologic examination of the surgical specimen showed the distal 14 cm. of the colon to be aganglionic. Following surgery there has been complete relief of symptoms with normal growth and development.

CASE XIV (J.C., CH125225). This four week old white male infant was admitted with the history of chronic constipation and intermittent episodes of vomiting and diarrhea since birth. The pregnancy was considered uneventful and delivery was accomplished by cesarean section. The birth weight was 8 pounds, 3 ounces. Barium enema examination at four weeks of age revealed a long dilated sigmoid colon in comparison with the rectum and the transverse and descending colon. Stasis of barium at one, twenty and twenty-eight hours, particularly in the lower sigmoid colon, with a relatively small rectum was observed. These findings were considered indicative of Hirschsprung's disease with the aganglionic segment extending from the anus to the rectosigmoid junction. The hospital course was uneventful and the patient was discharged on medical management. Colonic function was maintained by a strenuous and conscientious regimen of frequent enemas, catharsis and digital manipulation of the anus. A barium enema examination at nine months of age demonstrated a mild stasis of barium in the colon at two hours with a short, relatively narrow segment above the anus. The patient was admitted to Boston Floating Hospital at eleven months of age where a rectal biopsy confirmed the diagnosis. At twelve months of age the patient underwent proctectomy by Dr. Orvar Swenson. The aganglionic segment extended from the rectosigmoid junction to the anus. The child was last seen at eighteen months of age appearing normal in all respects with no recurrence of the previous symptoms.

CASE XV (G.Y., CH126467). This white male infant was first seen at three days of age with constipation since birth. Barium enema examination revealed no intrinsic organic defect or obstruction, but the sigmoid loop was observed to be very long and of large caliber. A large part of the barium was evacuated in fifteen minutes but stasis of barium at twenty-four and forty-eight hours suggested the possibility of Hirschsprung's disease. Conservative therapy was instituted and at six months of age barium enema examination demonstrated a dilated sigmoid colon with a disparity in caliber between the sigmoid colon and rectum, but a large amount of barium was evacuated in fifteen minutes. At seven months of age the patient was admitted to Boston Floating Hospital where a rectal biopsy confirmed the diagnosis of Hirschsprung's disease. At nine months of age the infant was admitted to this hospital for removal of a fecal impaction and was subsequently discharged. The patient was re-admitted to Boston Floating Hospital at fourteen months of age and underwent a sigmoidoproctectomy by Dr. Orvar Swenson. The child was last seen at twenty-two months of age and appeared normal in all respects.

CASE XVI (D.W., CH126606). This white male infant was first admitted at nine months of age with a history of constipation since birth. Physical examination revealed a markedly distended, tympanitic abdomen. Barium enema examination showed a dilated colon with abnormal stasis of barium at five and twenty-four

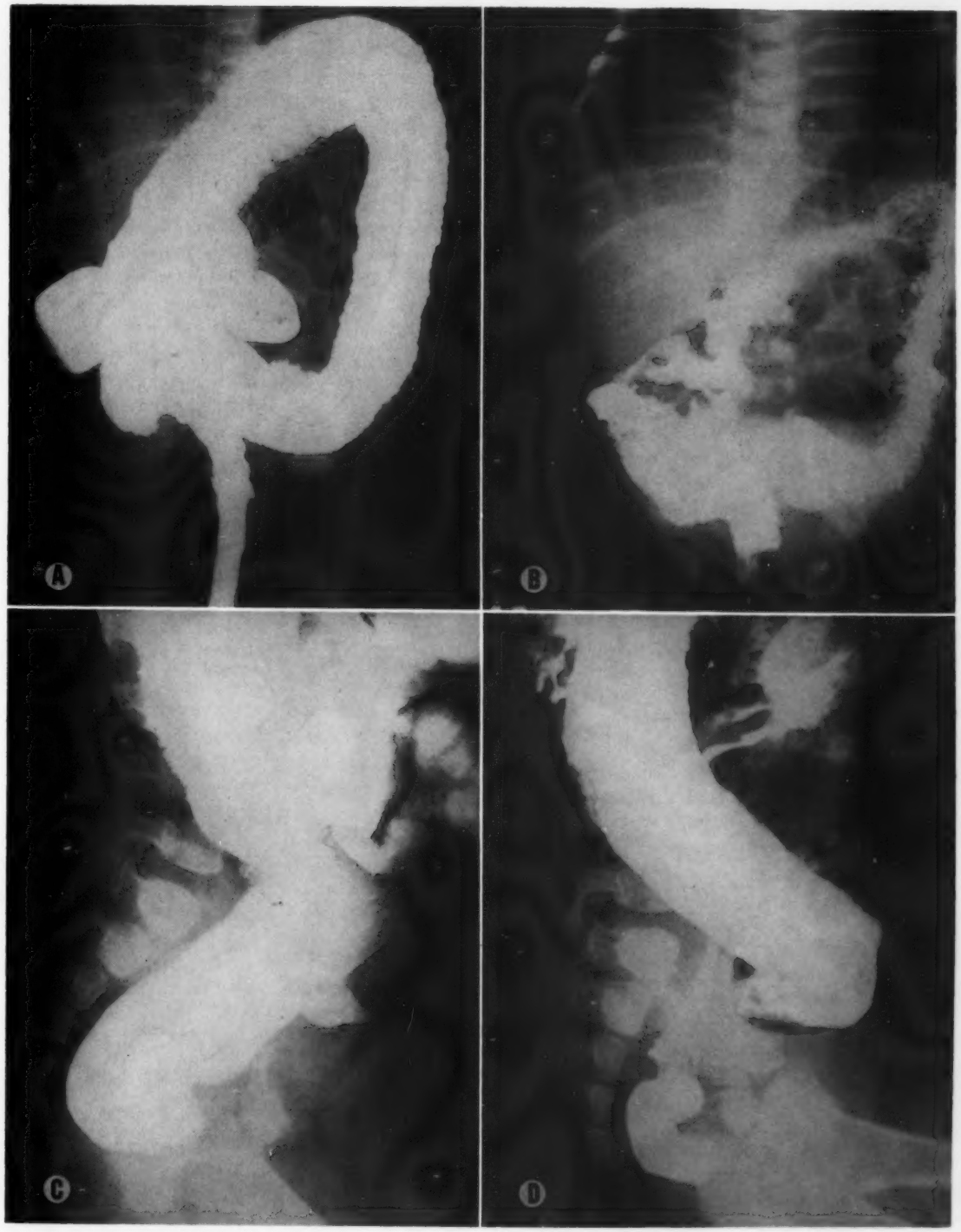

Fig. 7. Case XIII. Hirschsprung's disease not recognized at barium enema examination at thirteen days of age (*A* and *B*). At fifteen months of age (*C*) the aganglionic segment is shown to be distensible with the disparity in caliber between the aganglionic and ganglionic segments not evident until the study at seventeen hours (*D*).

hours, and at this time a caliber disparity became evident between the lower sigmoid colon and rectum. Marked stasis was still noted at five days, indicating a severe degree of Hirschsprung's disease with decompensation of the proximal colon. On the fifteenth hospital day, a right transverse colostomy was performed and considerable inspissated barium was removed by irrigation. This barium had been retained for thirteen days despite attempts to remove it by repeated enemas per anum. The patient improved rapidly following the colostomy and was subsequently discharged. At eleven months of age the patient was re-admitted for revision of the colostomy, and at nineteen months of age a Swenson type operation was performed with resection of the colon from the mid-sigmoid to the anus. Pathologic study of the specimen revealed the distal 7.5 cm. of colon to be aganglionic. At twenty-one months of age the colostomy was closed. The child appeared healthy with a normal height and weight at two years of age.

CASE XVII (R.L., CH138639). This Negro male infant was born by cesarean section to a diabetic mother. The birth weight was 6 pounds and the infant responded well at birth. At four days of age he was transferred to this hospital because of vomiting and failure to have normal stools. Physical examination revealed a markedly distended abdomen which was tympanitic throughout. The infant was placed on antibiotics and intravenous fluids with a diagnosis of sepsis. The symptoms subsided promptly and he was discharged at twenty-four days of age. The infant did fairly well for one month and then developed marked constipation which was relieved by suppositories and enemas. At five months of age the patient was re-admitted because of marked constipation. Barium enema study revealed a disparity of caliber between the sigmoid colon and rectum with a markedly abnormal stasis of barium at twenty-four, forty-eight and ninety-five hours. These findings were considered diagnostic of Hirschsprung's disease. The infant was given repeated peroxide enemas with relief of the abdominal distention and subsequently was discharged. It was felt that medical management would be utilized until a definite corrective surgical procedure could be undertaken. The patient at eight months of age requires frequent enemas to evacuate the colon.

CASE XVIII (C.M., CH139205). This Negro male infant was transferred from another hospital at three days of age with the history of bile stained vomiting and abdominal distention for forty-eight hours. The prenatal course and delivery were uneventful with a birth weight of 7 pounds, ¾ ounce. Physical examination revealed a markedly distended abdomen which was tympanitic to percussion. Bowel sounds were hyperactive. Barium emema examination at three days of age showed a markedly abnormal colonic stasis of barium at three, twenty-four and forty-two hours and a disparity in caliber between the mid and distal sigmoid colon. The findings were considered indicative of Hirschsprung's disease. The infant was treated conservatively by continous gastric suction and intravenous fluids with improvement. Barium enema examination at eleven days of age disclosed an improvement in the evacuation of the barium with some stasis at six and twenty-three hours but complete evaucation at seventy-two hours. Because of the apparent improvement in evacuation of the barium, the infant was discharged at thirteen days of age on medical management. At three weeks of age the patient was re-admitted to the hospital with vomiting, diarrhea and abdominal distention of three days' duration. Physical examination revealed a chronically ill, poorly nourished infant with a distended abdomen. On the eighth hospital day, a right transverse colostomy was performed and functioned well. The infant's condition deteriorated and on the twelfth postoperative day he developed a bronchopneumonia. In spite of intensive intravenous fluids and antibiotic therapy he expired at forty-nine days of age. Postmortem examination revealed the colon to be aganglionic from the junction of the descending and sigmoid colon to the anus. The immediate cause of death was an extensive staphylococcic pneumonia and septicemia.

CASE XIX (D.S., CH144612). This white male infant was first admitted at four days of age with bile stained vomiting and abdominal distention of three days' duration. The pregnancy was uneventful and the infant was delivered spontaneously with a birth weight of 8 pounds, 11 ounces. Physical examination revealed a feverish infant with a distended abdomen, passing a foul smelling stool. The infant was treated with antibiotics, blood and plasma with a rapid recovery and subsequent discharge at eight days of age. He was re-admitted at

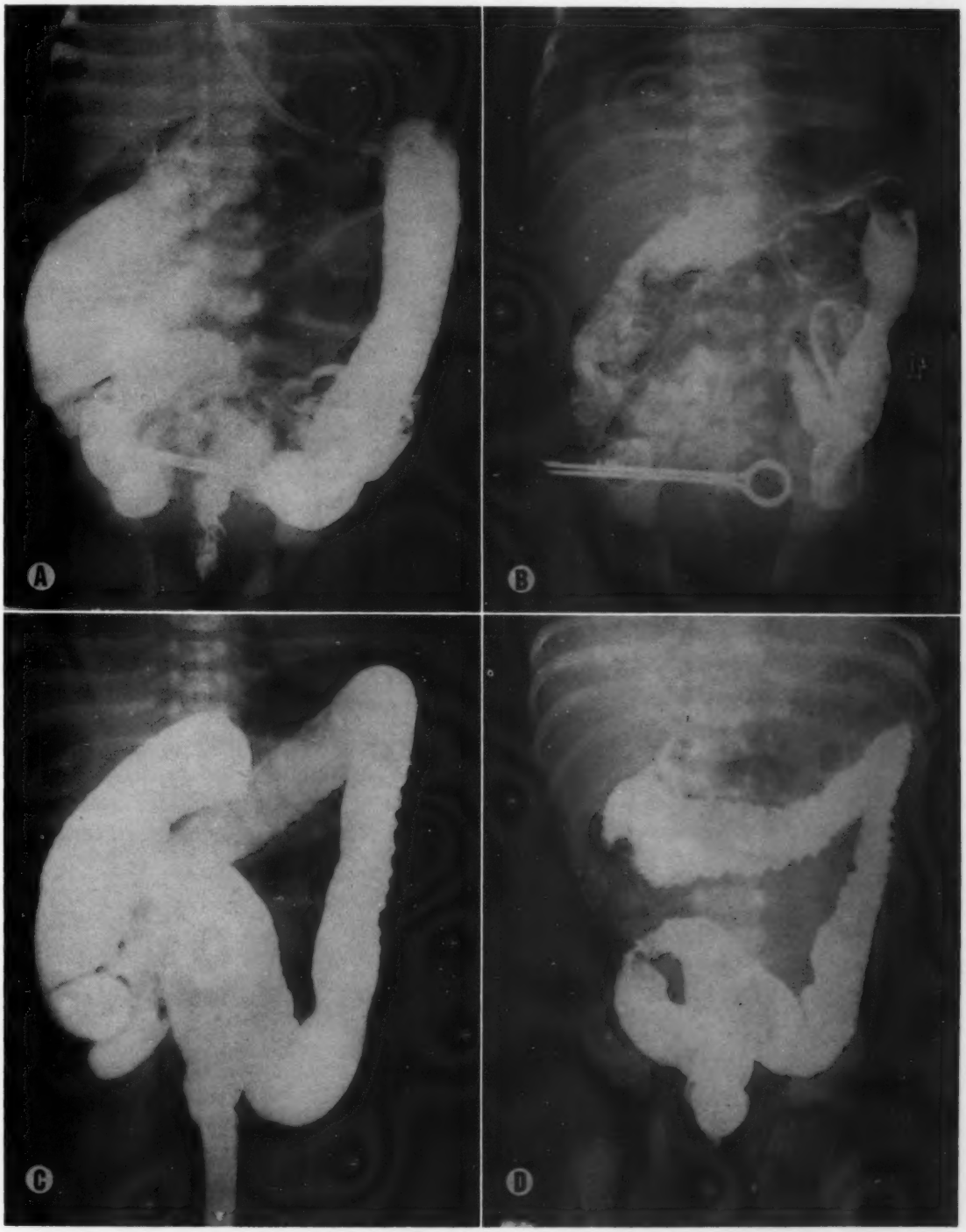

Fig. 8. Case xviii. Abnormal colonic stasis and slight caliber disparity demonstrated by barium enema examination at three days of age (*A* and *B*). Stasis again demonstrated at eleven days of age but with no appreciable caliber disparity (*C* and *D*). Diagnosis of Hirschsprung's disease confirmed at autopsy.

fifteen days of age with progressive vomiting and constipation of five days' duration. Physical examination revealed an acutely ill infant with a markedly distended abdomen. Barium enema examination at fifteen days of age demonstrated a marked narrowing of the rectum and distal sigmoid colon with dilatation of the descending and transverse colon. Marked stasis of barium was observed at fifteen and twenty hours in the dilated transverse and descending colon. The findings were considered typical of Hirschsprung's disease with the aganglionic segment extending from the anus to the mid-sigmoid colon. On the second hospital day a sigmoid colostomy was performed, and during surgery there was noted to be caliber disparity between the mid and lower sigmoid colon. A biopsy was taken from the contracted lower sigmoid colon which revealed "absence of the myenteric plexus." Following surgery the patient convulsed and became cyanotic. From this point on the course was downhill and at twenty days of age he expired. No postmortem study was obtained.

CASE XX (J.D., FB). This seven month old white male infant was referred for barium enema examination with the history of intermittent constipation for four months. The pregnancy and labor were considered normal. The infant was delivered spontaneously with a birth weight of 8 pounds, 12 ounces. Barium emema examination revealed a slight disparity in caliber between the rectum and descending sigmoid colon with abnormal stasis of barium in the colon at twenty-four hours. These findings were considered indicative of Hirschsprung's disease with the aganglionic segment extending from the anus to the rectosigmoid junction. The patient did well but required multiple enemas and suppositories for evacuation of the colon. At ten months of age the patient was admitted to Boston Floating Hospital where a resection of the aganglionic segment and proctosigmoidoscopy were performed by Dr. Orvar Swenson. At nineteen months of age barium enema examination revealed no intrinsic abnormality or caliber disparity. Evacuation was prompt and normal. Patient was last seen at twenty-one months of age appearing healthy in all respects with no recurrence of the previous symptoms.

CASE XXI (R.C., FB). This white male infant was born prematurely weighing 3 pounds. At first there was marked respiratory difficulty, cyanosis, and edema of the extremities. Vomiting occurred on the third day of life and on the following day the abdomen became tense and distended. There had been no bowel movements during the first four days. Enemas were administered and a large amount of meconium was evacuated on the sixth day following which the bowel movements became regular. During the next several months there were occasional complaints of constipation and at four months of age there was a period of four days without stool. The abdomen was often observed to be protuberant. At nine months of age a barium enema examination at another institution showed a normal colon although twenty-four and forty-eight hour examinations of the abdomen made at the insistence of the pediatrician revealed colonic stasis of barium. The infant was referred at eleven months of age for a repeat barium enema examination which demonstrated a dilated, elongated sigmoid colon. At twenty-four hours, abnormal colonic stasis of barium was noted, and at this time a caliber disparity became apparent between the lower sigmoid colon and the rectum. The findings were considered typical of Hirschsprung's disease with the aganglionic segment extending from the anus to the rectosigmoid junction. The patient was placed on a regimen of frequent enemas to aid colon evacuation. The infant was last seen at twelve months of age and considered to have a normal growth and development with a weight of 17 pounds, 10 ounces.

CASE XXII (L.R., CH152210). This eleven month old white female infant was admitted with the history of progressive constipation since two months of age. The patient weighed 7 pounds, 13 ounces at birth. The pregnancy was full term and the labor and delivery uneventful. The infant had one or two stools daily for two months then developed constipation requiring enemas and suppositories for relief. At five months of age the patient developed vomiting and diarrhea which responded to antibiotic therapy, and following this she had spontaneous bowel movements. This apparent improvement, however, ended abruptly after two weeks with the onset of severe constipation and marked abdominal distention. Enemas and suppositories were used constantly to maintain normal colon evacuation. The abdomen remained distended to varying degrees despite attempts to promote evacuation. At five

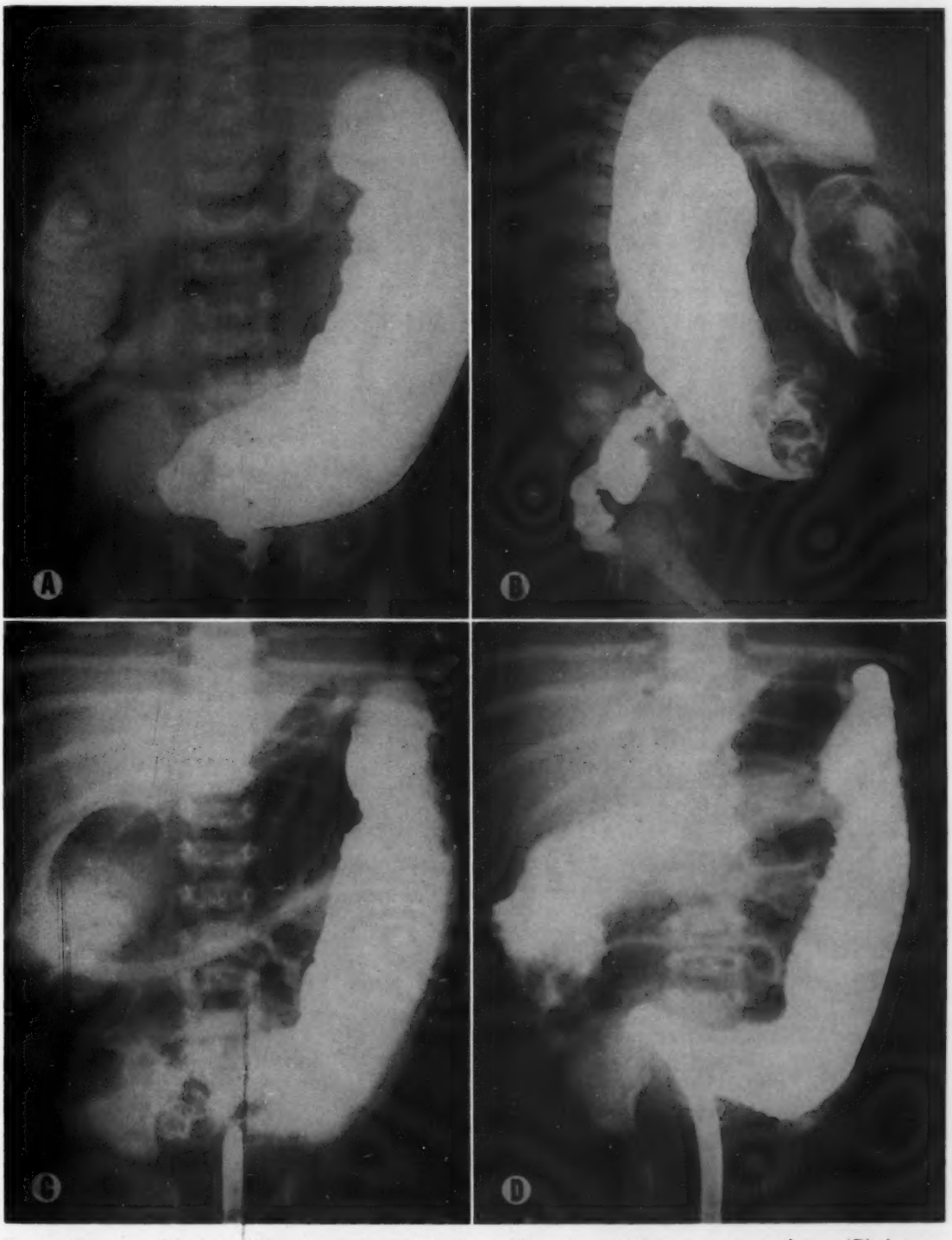

Fig. 9. Case xix. Marked caliber disparity and stasis at fifteen hours (*C*) and at twenty hours (*D*) demonstrated by barium enema examination at fifteen days of age (*A* and *B*). Rectal tube introduced to the splenic flexure of the colon at twenty hours does not significantly promote evacuation (*D*).

months of age the infant weighed 13 pounds, 9 ounces. Physical examination revealed a markedly distended tympanitic abdomen. The weight on admission at eleven months of age was 14 pounds, 13 ounces. Following admission, the patient was placed on cleansing enemas of saline and peroxide with fair results. On the second hospital day it was noted that the patient had prolapsed about 2.0 cm. of the rectum which was replaced manually. Barium enema examination revealed a marked distention of the sigmoid, descending and transverse colon by gas and fecal material. A caliber disparity was present between the sigmoid colon and rectum. Abnormal colonic stasis of barium was noted at three and twenty-four hours. The findings were typical of Hirschsprung's disease with the aganglionic segment extending from the anus to the rectosigmoid junction. At eleven months of age a sigmoid colostomy was performed.

CASE XXIII (A.D., CH 152280). This premature white male infant was born of a breech delivery weighing 5 pounds, 2½ ounces and being the first born of a twin pregnancy. The infant had no stools for the first thirty-six hours and enemas were given to aid evacuation. At one week of age the infant developed vomiting and abdominal distention. A barium meal examination was performed at fifteen days of age revealing a grossly dilated descending and sigmoid colon at twenty-four hours suggesting an infantile type of Hirschsprung's disease. At eighteen days of age the infant was transferred to this institution where physical examination revealed a distended abdomen with dilated superficial abdominal veins. Roentgen examination of the abdomen showed a markedly abnormal stasis of barium in the colon at four days from the previous upper gastrointestinal study. At six days no further evacuation of barium was noted and at this time a slight disparity in caliber became apparent between the dilated sigmoid colon and the smaller rectum. Despite frequent peroxide enemas, the colon remained distended and at twenty-two days of age a right transverse colostomy was performed. Following this surgical procedure, the infant developed an electrolytic imbalance which was treated with whole blood, plasma and intravenous fluids. The infant's course, however, continued downhill and at twenty-five days of age he expired. Postmortem examination revealed the distal 7.5 cm. of the colon to be aganglionic from the anus to the region of the junction of the rectum and the sigmoid colon. Some peritoneal effusion and fecal peritonitis and a left hemorrhagic pyelonephritis were also found.

CASE XXIV (R.B., FB). This four year old white male child was referred for barium enema study with a history of constipation beginning at four months of age and becoming progressively more severe. Frequent catharsis and enemas were necessary to evacuate the colon. The pregnancy was uneventful but labor was induced at eight months gestation with a normal delivery and a birth weight of 7 pounds, 1 ounce. The neonatal period was uneventful and the child developed normally both as to height and weight. Barium enema study at four years of age revealed a rectum of large caliber and a long sigmoid colon extending into the right upper abdomen. At one hour very little evacuation of barium had occurred, and at twenty-four hours considerable gas and barium still remained in the colon and rectum. These findings were interpreted as a simple chronic constipation. The child continued to experience difficulty and four months later was admitted to Boston Floating Hospital where a rectal biopsy revealed an absence of ganglion cells. Four days following the rectal biopsy a coloproctectomy was performed by Dr. Orvar Swenson. Pathologic examination confirmed the diagnosis of Hirschsprung's disease involving the distal colon. Following surgery, the patient has been completely asymptomatic, and barium enema examination six months postoperatively revealed no intrinsic abnormality and a normal evacuation of barium.

CASE XXV (F.B., CH134087). This white male infant was first admitted at one and one-half years of age with a history of diarrhea and failure to gain weight. The child had had three previous admissions at another hospital because of recurrent vomiting beginning at four weeks of age. Five months prior to this admission, the patient had an ileotransverse colostomy for an obstruction in the terminal ileum. The pregnancy and labor were uncomplicated with a birth weight of 6 pounds, 11 ounces. Physical examination showed a distended, tympanitic abdomen. Barium enema examination revealed a large colon with abnormal retention of barium at one, eighteen and forty-two hours and with traces of barium still pres-

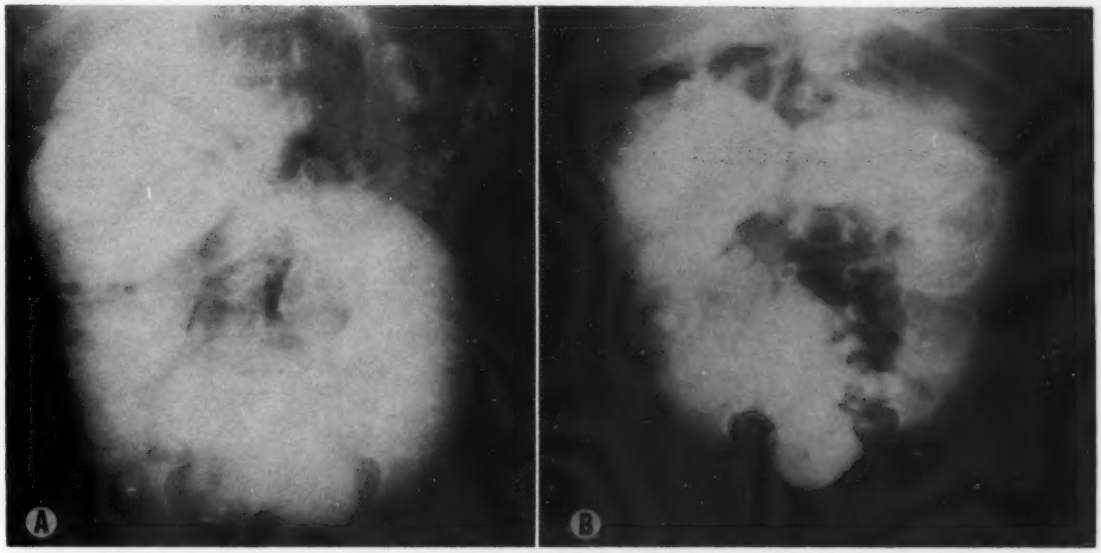

Fig. 10. Case xxv. Marked stasis occurring at forty-two hours (*A*) and forty-eight hours (*B*) after barium enemas administered at nineteen (*A*) and twenty-two (*B*) months of age in case having a small intestine blind loop syndrome resulting from a jejunotransverse colostomy for ileal stenosis.

ent at five days. This abnormal colonic stasis of barium was considered suggestive of Hirschsprung's disease. A small bowel study was performed revealing a normal small bowel pattern with barium entering the dilated colon near the hepatic flexure. A rectal biopsy was obtained but proved inconclusive, and the patient was discharged under medical management. He was re-admitted at twenty-two months of age because of abdominal distention and appeared chronically ill and malnourished on admission. Barium enema examination revealed barium in several loops of dilated bowel, and at this time reduplication of the colon was considered with a marked stasis of barium in the "duplicated colon" at forty-eight hours. The patient continued to lose weight in the hospital and on the fifth hospital day an exploratory laparotomy was performed which revealed a blind loop syndrome involving the entire ileum with partial stenosis of the distal portion of the ileum and a jejunotransverse colostomy. Surgical correction

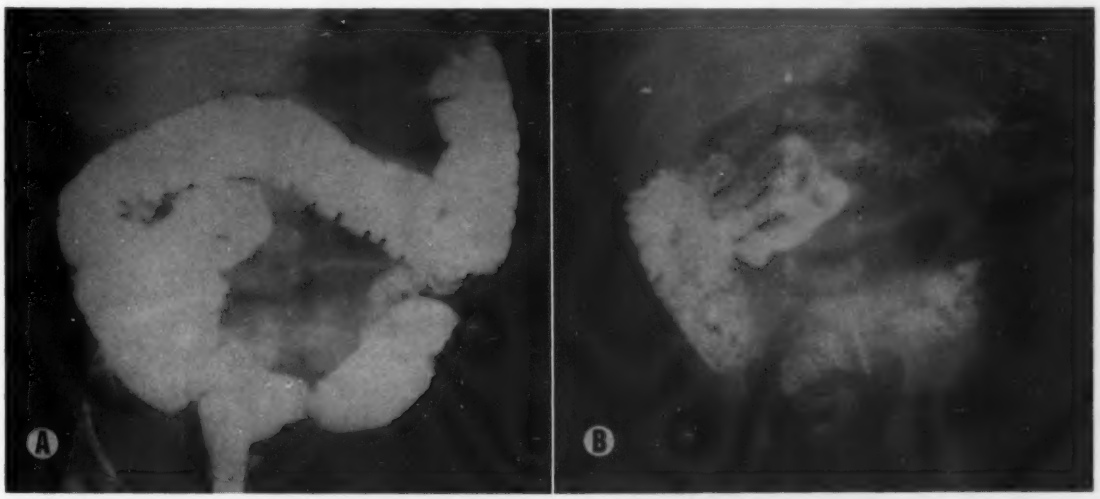

Fig. 11. Case xxvi. Normal evacuation of the colon following a barium enema examination in an infant with a high degree of ileal stenosis (*A* and *B*).

FIG. 12. Case XXVII. Barium enema examination with fairly prompt and satisfactory evacuation of the barium in a newborn infant with the meconium plug syndrome (*A* and *B*). The meconium ileus of fibrocystic disease of the pancreas was excluded by subsequent studies.

was attempted bypassing the stenotic ileum by an ileoileostomy. Following surgery, the patient showed a marked improvement in growth and has had no recurrence of the previous symptoms. The patient was re-examined at two and one-half years of age. The gastrointestinal series revealed stasis of barium in the ileum at twenty-four hours but complete evacuation at seventy-two hours. Barium given by enema was again retained in the small bowel and colon at two, five and twenty-four hours.

CASE XXVI (D.S., CH102318). This ten day old white female infant was admitted with a history of bile stained vomiting after each feeding for three days. Her stools were said to be normal. Pregnancy and delivery were uneventful. The birth weight was 6 pounds. Physical examination revealed a listless infant with a slightly distended and tympanitic abdomen. Barium enema examination disclosed no organic obstruction of the colon or terminal ileum, and normal evacuation was noted. Several loops of small bowel were observed to be distended with gas indicating a partial small bowel obstruction near the junction of the jejunum and ileum. On the second hospital day an exploratory laparotomy was performed and a stenosis was found in the proximal ileum. An enteroenterostomy was performed with complete recovery and discharge on the tenth postoperative day.

CASE XXVII (J.R., CH122091). This two day old white female infant was admitted with a history of vomiting for a period of twenty-four hours. The pregnancy and labor were uneventful. The infant was born spontaneously and weighed 6 pounds, 10 ounces at birth. Physical examination revealed marked abdominal distention but otherwise was not remarkable. Barium enema examination at two days of age disclosed no intrinsic organic lesion of the colon, but there was the appearance of some gas and/or meconium in the proximal colon. Numerous gas distended loops of small bowel were noted, indicating a partial small bowel obstruction. A large part of the barium was expelled promptly. The clinical impression was meconium ileus. At two days of age an exploratory laparotomy was performed with resection of 8 to 10 inches of the distal ileum which was

narrowed and filled with meconium having a putty-like consistency. An ileostomy was also accomplished and attempts were made to remove the meconium by enemas containing pancreatin. At twelve days of age the ileostomy was closed by end to end anastomosis. Pathologic examination of the resected ileum was considered compatible with meconium ileus. Following surgery, the patient experienced an extremely stormy course developing pneumonia and periodic vomiting. Stools for trypsin were consistently negative. In the second postoperative month, the patient showed some weight gain and improvement. A barium enema examination at two months of age revealed no intrinsic organic abnormality. The patient was subsequently discharged weighing 7 pounds, 5 ounces with the diagnosis of mucoviscidosis. The patient was re-admitted at three months of age for surgical correction of an ileal fistula which developed subsequent to the previous surgery. This was accomplished by an ileotransverse colostomy bypassing the fistula. Roentgen studies of the chest at three months of age revealed no evidence of fibrocystic disease of the pancreas. In spite of the bypassing procedure, the infant continued to pass fecal material by way of the fistula. The patient has had several re-admissions for blood transfusion, the last of which was at sixteen months of age. Repeated duodenal drainage examinations revealed 55 per cent normal activity of trypsin and several "sweat tests" have been within normal limits. Numerous roentgenographic studies of the chest at different intervals have given no indications of fibrocystic disease of the pancreas. Although the patient has been followed as a possible mucoviscidosis, there is considerable clinical reservation concerning this diagnosis, and it is now thought that the original condition was one of a severe degree of the meconium plug syndrome.

CONCLUSIONS

The roentgen diagnosis of Hirschsprung's disease depends on the recognition of the pathologic physiology resulting from a microscopic anatomic lesion in the bowel which causes bowel obstruction. The manifestations of this pathologic physiology vary markedly in time of onset and in severity in different patients. Abnormal stasis in the bowel especially in newborns and young infants is an early, dependable, and fairly specific sign. Examinations should be made twenty-four and forty-eight hours following a barium enema for the recognition of this sign. Dilatation and hypertrophy of the bowel proximal to the lesion often occur later and are dependent more on the duration and less on the severity of the obstruction.

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PAPILLARY CALCIFICATION IN NECROTIZING RENAL PAPILLITIS*

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RENAL papillary calcification may be the first roentgen sign of necrotizing renal papillitis. Nephrocalcinosis and calcium encrusted necrotic papillae have been mentioned in previous reports, but the calcification has not been demonstrated on roentgenograms and the importance of the observation has not been emphasized.

The interest in the roentgenologic aspects of necrotizing renal papillitis has been demonstrated by the publication of three articles[2,4,8] during the first nine months of 1956. Only two articles,[3,7] on the subject had appeared in the radiologic

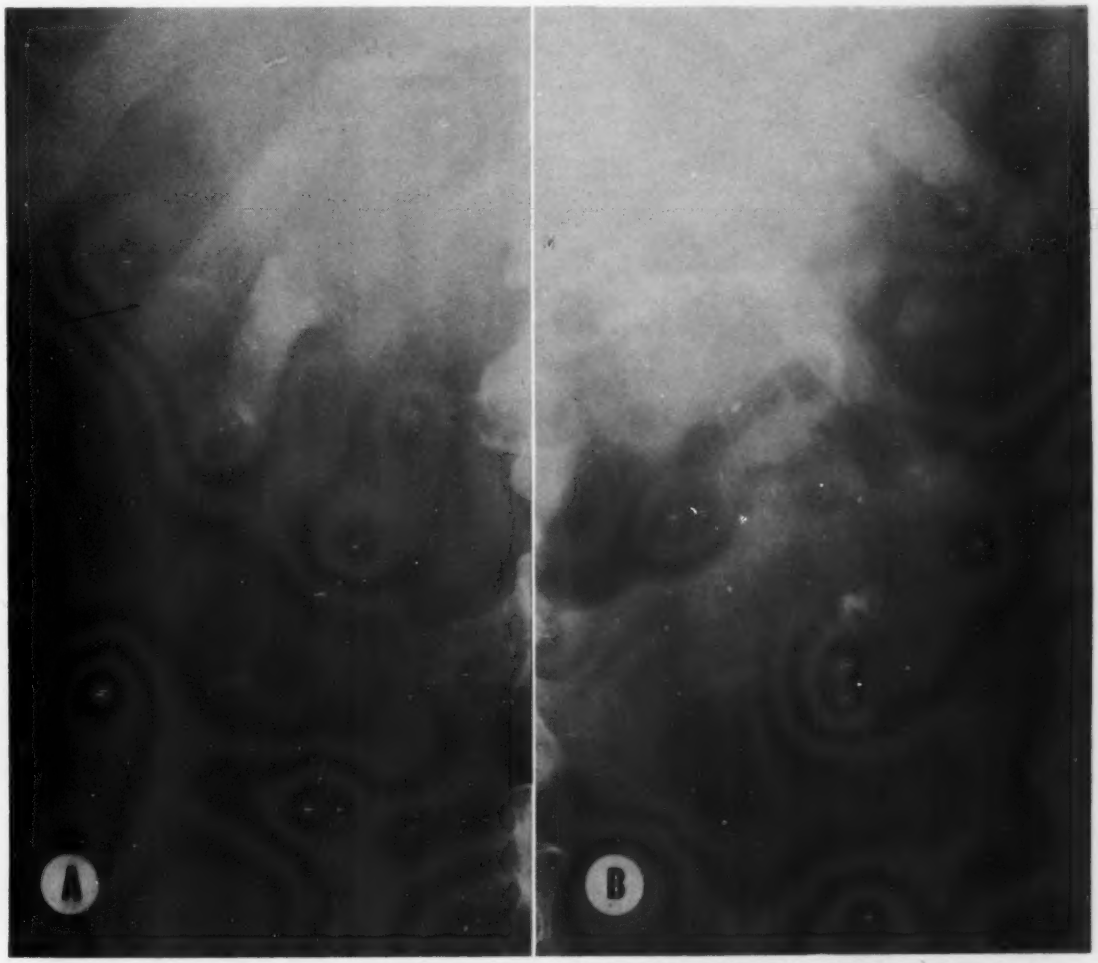

FIG. 1. Intravenous urogram. (*A*) Right kidney; (*B*) left kidney. Dilatation of the collecting system is present. Radiolucent halos or "ring shadows" which indicate necrotizing renal papillitis are present.

* From the Department of Radiology, University of California School of Medicine, San Francisco, California. Presented at the Tenth Annual Meeting of the United States Public Health Service Clinical Society, National Institutes of Health, Bethesda, Maryland, April 26, 1956.

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FIG. 2. Laminagram of right kidney. The laminagram made after the intravenous pyelogram shows rims of calcium. Note that the calcium rims and the opaque media "ring shadows" are similar in shape and surround the necrotic papillae.

literature in the preceding sixty years. This new interest seems to be related to the improved prognosis of the disease with antibiotic treatment.

The roentgen diagnosis of necrotizing renal papillitis has been thoroughly discussed in recent articles.[2,4,8] We wish to illustrate the important contribution which roentgen demonstration of renal papillary calcification may make to the diagnosis of this disease.

REPORT OF A CASE

A twenty-five year old white woman was admitted to the University of California Hospital on March 14, 1955 for evaluation of diabetes mellitus which had been diagnosed at the age of eight years. The control of her diabetes had been poor with numerous insulin reactions, episodes of hyperglycemia and glycosuria. During the six years prior to this admission, she had taken globin insulin, 35–40 units before breakfast and 8–15 units before supper. Physical examination revealed a blood pressure 140/100 and Grade III retinopathy of both fundi with numerous microaneurysms and flame-shaped hemorrhages. The discharge diagnosis was: diabetes mellitus with diabetic retinopathy and early hypertension.

The second hospital admission on July 1, 1955 was for acute glaucoma of the left eye. On July 8, 1955 a renal needle biopsy was performed under fluoroscopic control.[5] Minimal postoperative hemorrhage ensued and there was temperature elevation to 101° F. which promptly subsided. The biopsy revealed severe intercapillary glomerulosclerosis.

A third hospital admission on July 18, 1955 was required because of left costovertebral angle pain and vomiting. The urine contained many white blood cells, red blood cells, and the culture revealed numerous gram-negative rods of the proteus Group. An intravenous pyelogram on August 18, 1955 demonstrated excavations of the renal parenchyma in both kidneys

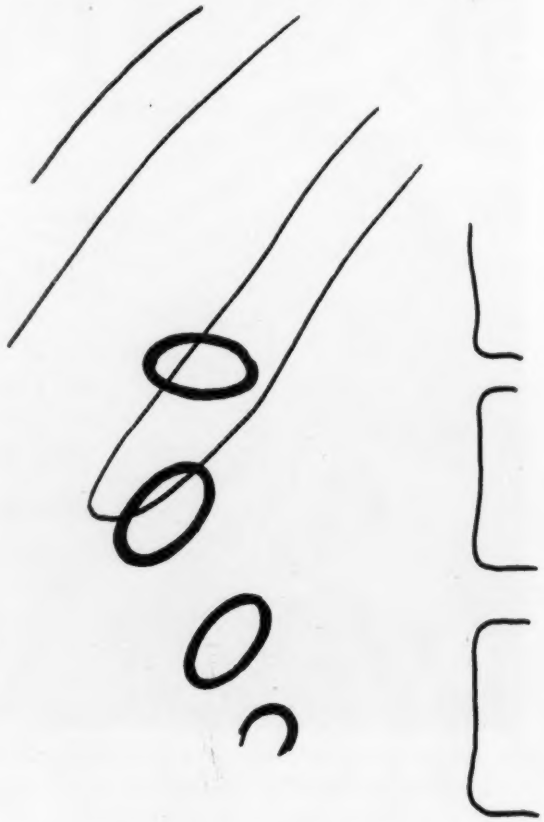

FIG. 3. Illustration to show the calcium rims demonstrated by laminagraphy (Fig. 2).

Fig. 4. Calcium shells surrounding necrotic papillae. Information from the laminagrams suggests that the necrotic papilla acts as a nidus around which calcium is deposited.

(Fig. 1). The renal papillae were surrounded by opaque medium and one of the renal papillae contained a rim of calcium. Laminagrams of the kidneys revealed at least four calcified papillae in the right kidney and two calcified papillae in the left kidney (Fig. 2 and 3). A roentgen diagnosis of necrotizing renal papillitis was made at this time.

The roentgenogram of the abdomen dated July 19, 1955 was reviewed and small calcium deposits were noted in the region of the calcified papillae later demonstrated on the intravenous pyelogram. The calcium deposits were overlooked because of the low degree of visibility. Laminagrams of the kidney would have been helpful in locating such poorly defined calcium deposits. The renal laminagrams taken at a later examination clearly demonstrated details of the calcification not seen on the film of the abdomen. In retrospect, we feel that this calcification was an indication of the developing necrotizing renal papillitis. In November, 1955, a urinalysis revealed necrotic renal tissue and the diagnosis of necrotizing renal papillitis was established. With large doses of antibiotics, careful diet and insulin regulation, the patient survived the acute episode. However, recent intravenous urograms have showed further calyceal dilatation and calcification (Fig. 5).

DISCUSSION

The pathogenesis of necrotizing renal papillitis, a disease peculiar to patients with diabetes or urinary tract obstruction, has not been settled. The renal lesions have the appearance of infarct-like necrosis which may be ascribed to ischemia. With urinary tract obstruction, the cause of renal ischemia is apparent. Muirhead *et al.*[6]

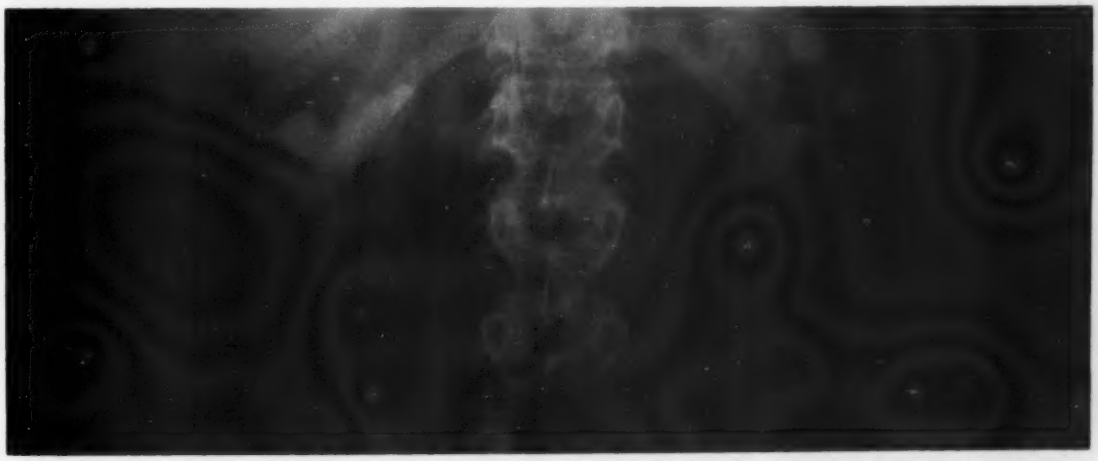

Fig. 5. Intravenous urogram seven months after the first urogram shows further dilatation of all calyces. Flask-shaped distention of left kidney calyces indicates that necrotic papillae have left the cavity.

demonstrated with dogs that occlusion of medullary vessels could result from lower ureter obstruction and increased intrapelvic pressure.

In patients with diabetes and without urinary tract obstruction, the renal ischemia may result from marked inflammatory reaction with subsequent pressure on the thin-walled capillaries that supply the papillae.

The pattern of the calcification which we found in this case interested us. A thin rim of calcium barely perceptible on the scout roentgenogram of the abdomen surrounded the renal papillae (Fig. 2 and 3). It is likely that this rim was composed of calcium salts deposited on a central nidus of necrotic tissue (Fig. 4). Experimental work by Borland and Jackson[1] in 1931 has suggested a cause for the renal calcification. In his experiments, rats were maintained on a fat-free diet which resulted in a nutritional deficiency of unsaturated long chain fatty acids. These rats developed circumscript necrosis of the renal papillae combined with calcification of the tubules. Robbins and Angrist[9] have suggested a parallelism between these experimental lesions and human lesions, for it may be significant that in the diabetic patient there exists a profound disturbance of fat metabolism.

This analogy is not entirely valid. Further investigation is needed to determine the role of renal ischemia and diet in the etiology of necrotizing renal papillitis with calcification.

SUMMARY

Calcification of renal papillae is presented as a significant roentgen sign in the diagnosis of necrotizing renal papillitis.

Calcified papillae are best demonstrated by laminagrams of the kidney.

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Vol. 78, No. 6

DIVERTICULAR URETERAL CHANGES*

A REPORT OF FOUR CASES

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THE ureteral changes reported here were discovered in 4 patients during retrograde ureterographic studies at Harper Hospital within a period of nine months. The roentgenograms suggest multiple, evenly-spaced diverticula of the ureters which are bilaterally demonstrated in 3 of the cases. The defects project outward from the ureteral lumen, are filled with the contrast medium, and are seen in all portions of the ureters.

The manifestations described are the first of the kind recorded as far as we have been able to ascertain, and their incidence, etiology and significance await more definitive histopathologic and clinical evaluation. This report is presented with some suggestions relative to their possible clinical importance.

REPORT OF CASES

CASE 1. A fifty-four year old colored female was first admitted to Harper Hospital on June 19, 1951. Her complaints were those of painful, frequent, and urgent urination. The recorded history was noncontributory and the physical examination revealed no pertinent abnormalities.

The routine blood study revealed a red blood cell count of 3.94 million, a hemoglobin of 9.9 gm. and a white blood cell count of 5.6 thousand with normal differential counts. The Kahn test was negative and a blood nonprotein nitrogen determination was 27.7 mg. per cent. The routine urinalysis obtained at the time of cystoscopy showed a specific gravity of 1.008 gm. per cc., 2 plus albumin, 10 to 15 white blood cells and 0 to 2 red blood cells per high power field. Urine cultures taken from the bladder and both ureters during cystoscopy revealed Pseudomonas aeruginosa growths.

Cystoscopy disclosed a severe chronic cystitis with multiple hemorrhagic areas covered by exudate. Retrograde pyelograms were reported as normal.

On October 25, 1951 the patient was readmitted with recurrent urinary frequency. The routine blood study was essentially unchanged, an anemia persisting. Urinalysis of a cystoscopic urine specimen showed the specific gravity to be 1.032 gm. per cc., 2 plus albumin, 6 to 10 white blood cells per high power field, occasional red blood cells, and two plus bacteria. Urine specimens from the bladder at cystoscopy were cultured. This growth indicated Escherichia coli. Both ureteral specimens were sterile.

The cystoscopic examination on the second admission demonstrated two urethral diverticula near the external meatus apparently arising from infected urethral glands (Fig. 1*A*). Mild cystitis and urethritis were seen.

On October 29, 1951 a diverticulectomy was done and two small cysts in the area of Skene's glands were resected. These showed histologic evidence of chronic inflammation surrounding the diverticula which were lined by transitional epithelium (Fig. 1, *B* and *C*).

This patient was admitted for a third time on September 25, 1956, complaining of nocturia and diurnal frequency with voiding pain. History and physical examination were essentially noncontributory. Routine blood study showed no abnormality at this time. Urinalysis of a specimen obtained through the cystoscope revealed a specific gravity of 1.008 gm. per cc., 1 plus albumin, 10 to 12 white blood cells and 5 to 10 red blood cells per high power field. The blood nonprotein nitrogen was 26.5 mg. per cent. Urine cultured from the bladder at the time of cystoscopy revealed Pseudomonas aeruginosa and Monilia growths.

Cystoscopy on September 29, 1956 disclosed acute hemorrhagic cystitis, and on October 1, 1956 repeat cystoscopy showed subsidence of the acute process. Pyelograms by retrograde injection of contrast medium on both occasions revealed multiple bilateral diverticulum-like irregularities along the ureters (Fig. 2, *A* and *B* and Fig. 3). Review of the 1951 roentgenograms showed similar ureteral changes which were unreported at that time (Fig. 2*C*).

* From Harper Hospital, Detroit, Michigan.

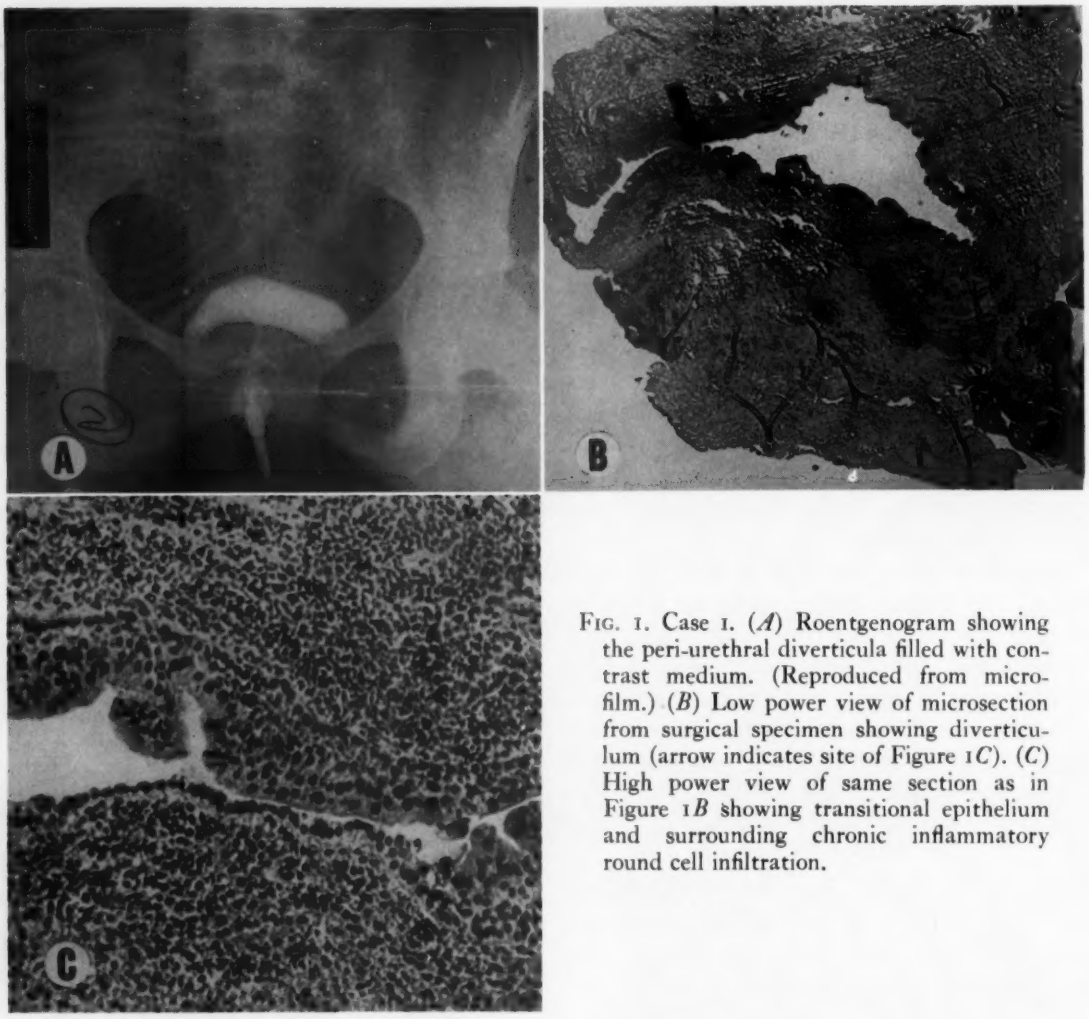

FIG. 1. Case 1. (*A*) Roentgenogram showing the peri-urethral diverticula filled with contrast medium. (Reproduced from microfilm.) (*B*) Low power view of microsection from surgical specimen showing diverticulum (arrow indicates site of Figure 1*C*). (*C*) High power view of same section as in Figure 1*B* showing transitional epithelium and surrounding chronic inflammatory round cell infiltration.

The patient has been symptom-free since antibiotic and sulfa drug therapy.

CASE II. A thirty-four year old white male was first admitted to Harper Hospital on March 27, 1956 because of a six-hour history of painless gross hematuria. No history of dysuria, fever, or constitutional symptoms could be elicited. The physical examination was unremarkable with the exception that digital rectal examination revealed a slightly enlarged, boggy, nontender prostate. The routine blood study was satisfactory. A blood nonprotein nitrogen was determined to be 38.2 mg. per cent. The Kahn test was negative. Analysis of a sterile urine specimen showed a specific gravity of 1.008 gm. per cc. and a slight trace of albumin, but no white blood cells and only occasional red blood cells were found per high power field. Urine cultures and smears for tuberculosis organisms were negative on two occasions.

Cystoscopy with retrograde pyeloureterography showed roentgenographic changes involving the inferior and middle calyces on the left side (Fig. 4). These were thought to suggest tuberculosis or a pseudodiverticulum. Visual inspection of the bladder revealed no disease process. Multiple diverticulum-like ureteral changes were also noted on the roentgenograms.

The patient was re-admitted on June 11, 1956 complaining of persistent pyuria and hematuria. Physical examination, blood studies, nonprotein blood nitrogen-determination, urine smears and cultures were again essentially negative. Urinalysis of a sterile specimen showed only occasional white blood cells but many bacteria.

A second retrograde pyelogram showed no

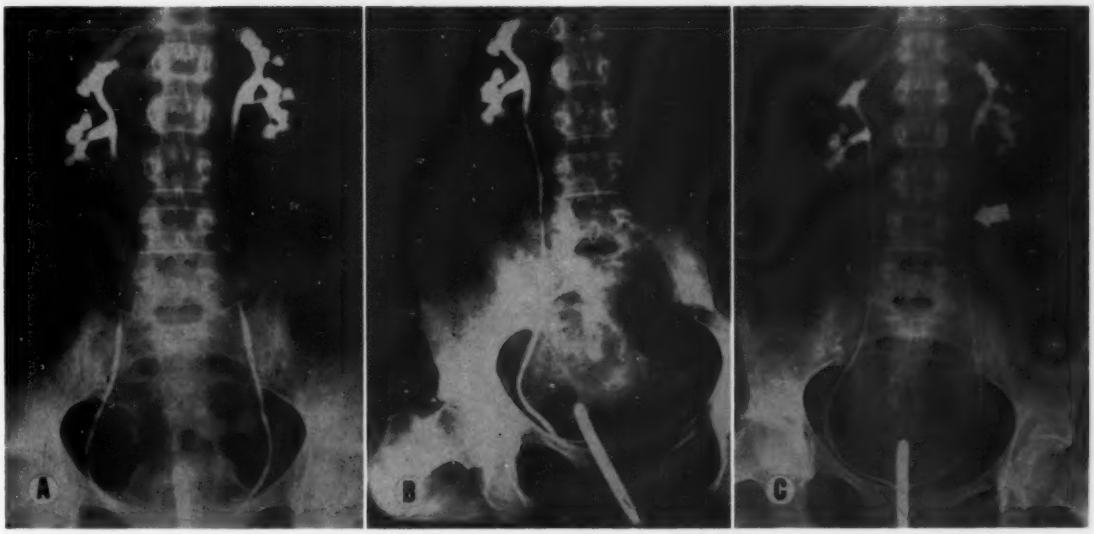

Fig. 2. Case I. (*A*) Retrograde ureteropyelogram showing multiple bilateral ureteral diverticular changes in upper middle thirds of the ureters. (*B*) Better filling of the right ureter shows persistence of the diverticular changes, especially above the right transverse process of the fifth lumbar vertebra. (*C*) Retrograde ureteropyelogram from microfilm dated 1951 showing poorly the diverticular ureteral changes bilaterally at that time (arrow indicates the region of some of the changes in the left ureter).

Fig. 3. Case I. Upper portion of the left ureter as shown through use of LogEtronography. The diverticular changes are clearly shown.

Fig. 4. Case II. The upper portion of the left ureter and lower left kidney pole by LogEtronography. This shows the diverticular changes of the ureter and the pseudodiverticular changes in the lower renal calyx.

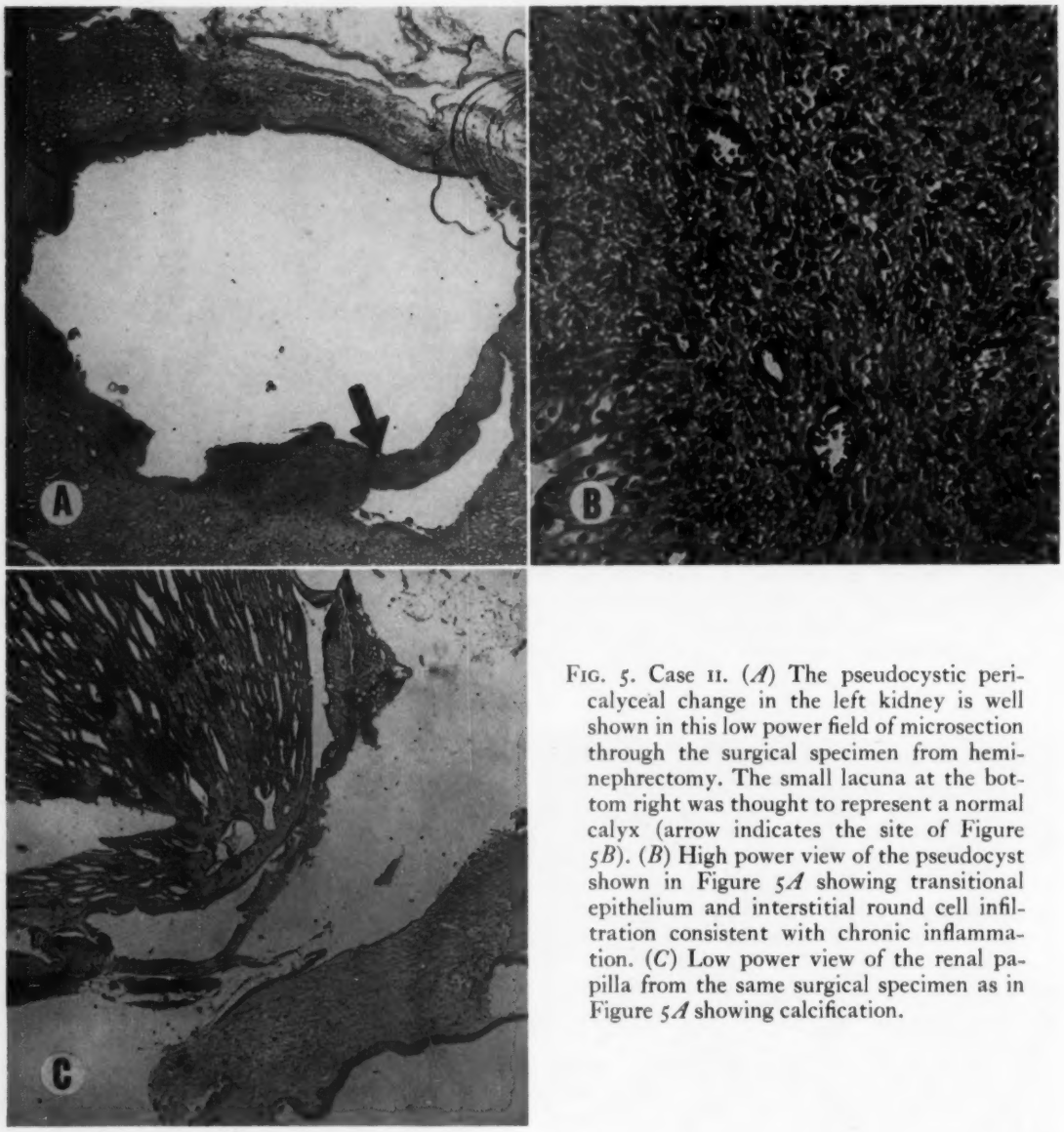

FIG. 5. Case II. (*A*) The pseudocystic pericalyceal change in the left kidney is well shown in this low power field of microsection through the surgical specimen from heminephrectomy. The small lacuna at the bottom right was thought to represent a normal calyx (arrow indicates the site of Figure 5*B*). (*B*) High power view of the pseudocyst shown in Figure 5*A* showing transitional epithelium and interstitial round cell infiltration consistent with chronic inflammation. (*C*) Low power view of the renal papilla from the same surgical specimen as in Figure 5*A* showing calcification.

change in the appearance of the upper excretory tracts. A left heminephrectomy was accomplished on June 19, 1956 to remove the calyceal diverticulum of the inferior pole. The pathologic report was that of chronic pyelitis, pseudocystic dilatation and multiple calcifications in the renal papilla (Fig. 5, *A*, *B* and *C*).

The patient made an uneventful postoperative recovery and has remained symptom-free. Urine studies have also been negative.

CASE III. The patient was a twenty-three year old colored female seen originally on July 27, 1956 in the emergency room of this institution because of acute hematuria, dysuria, frequency and urgency. She was much improved following a course of gantrisin therapy and was cystoscoped August 10, 1956. The blood studies, including a Kahn test and a nonprotein nitrogen determination, were unremarkable but urinalysis of a sterile specimen showed 13 to 18 white blood cells and 50 to 55 red blood cells per high power field, 1 plus albumin and many bacteria.

Cystoscopy revealed subsiding hemorrhagic cystitis. The bladder and ureteral urine specimens were cultured and only the former showed

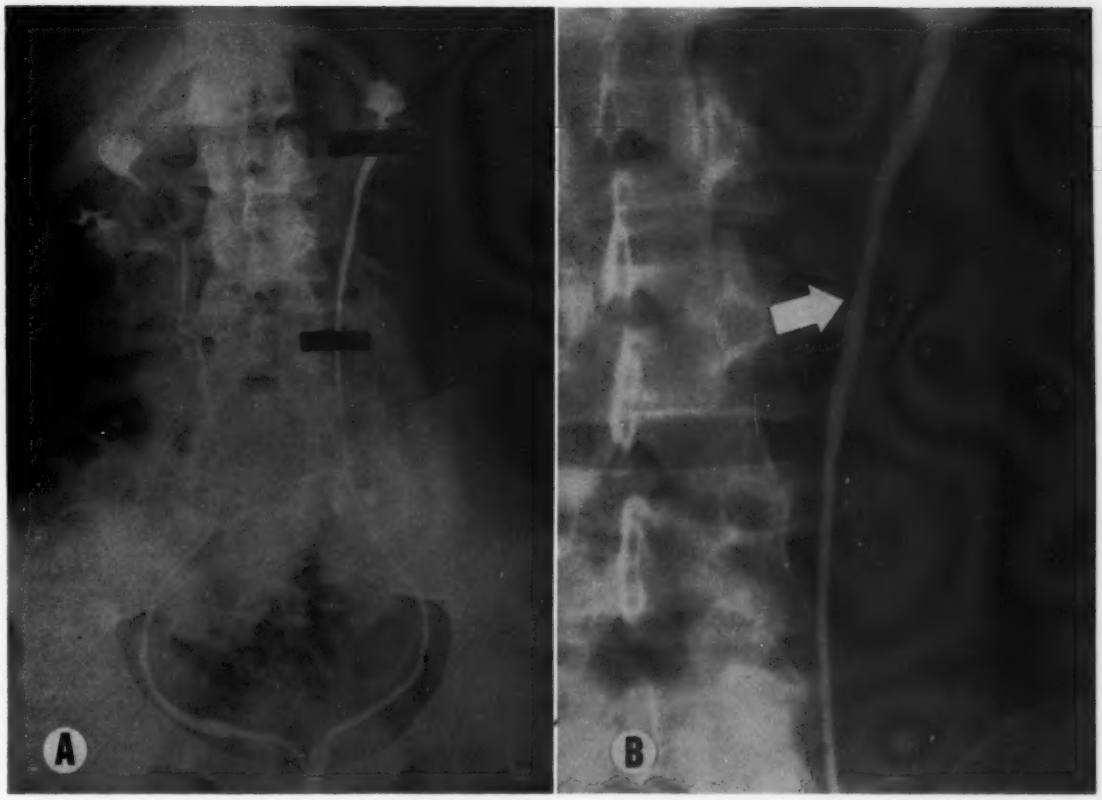

Fig. 6. Case III. (*A*) Retrograde ureteropyelogram showing the congenital variation present (the two bars indicate the limit of the diverticular ureteral changes in this case). (*B*) Photographic enlargement of the left ureteral area blocked off in the previous figure (arrow indicates region of greatest changes).

growth. This was of Aerobacter aerogenes. Retrograde pyelograms indicated bilateral duplications of the renal pelves and ureters. In addition, multiple radiopaque ureteral projections were noted (Fig. 6, *A* and *B*).

This patient was managed with gantrisin and when last seen on January 28, 1957 was free of complaints and in the third month of pregnancy.

Case IV. An eighty-five year old colored female was hospitalized on February 27, 1957 complaining of chronic left costovertebral angle and flank pain of six to seven months' duration. This constant pain became sharp and severe at times, particularly just prior to this admission. The patient described occasional associated dysuria but denied fever, chills, hematuria, nausea and vomiting. There was no other pertinent history. Physical examination revealed generalized arteriosclerosis and some left costovertebral angle tenderness. The routine blood study was unremarkable. A blood nonprotein nitrogen was determined to be 31.7 mg. per cent. A Kahn test was negative. Urinalysis indicated a specific gravity of 1.020 gm. per cc., 1 plus albuminuria, 20 to 30 white blood cells and 1 to 3 red blood cells per high power field. Urine cultures obtained from each ureter and the bladder revealed Escherichia coli growth from all three specimens.

Cystoscopy on March 4, 1957 showed clear cysts at the vesicle neck at 3 and 9 o'clock with similar cysts throughout the bladder mucosa. A moderate amount of trigonitis and bladder trabeculation was noted and it was thought that a large bore urethral stricture was also present.

Roentgenograms revealed a calculus in the inferior calyx of the left kidney and ptosis of the right kidney. In addition, diverticular ureteral changes were noted bilaterally (Fig. 7, *A* and *B*).

Surgical removal of the calculus was rejected because of the patient's age and conservative management with gantrisin was started. This has been successful to date.

FIG. 7. Case IV. (*A*) Photographic enlargement of lower third of the right ureter from a bulb-type retrograde ureteropyelogram showing diverticular changes in area of apparent ureteral irregularity (arrows indicate larger diverticula). (*B*) Left ureteropyelogram showing extensive diverticular ureteral changes in the upper and middle thirds of the ureter.

SUMMARY OF CASE FINDINGS

All 4 patients had some urinary tract infection which was chronic in 2 and acute in the others. One patient showed a calyceal calculus while 3 of the patients had anatomic urinary tract abnormalities of an acquired or congenital nature in addition to the diverticulum-like ureteral changes. The latter were seen bilaterally in 3 patients and unilaterally in the fourth. In 1 case the ureteral changes were demonstrated five years prior to the most recent examination. One patient had roentgenographic evidence of radiopaque medication in her buttocks without a history to suggest its nature. All 4 patients had negative Kahn tests. Each of the patients was examined by a different urologist whose retrograde pyelographic injection technique differed from that of the others. The instruments and media used, however, were essentially similar. Intravenous pyelography was not done in any case. Three of the patients have remained clinically well for the intervening months to the present date after correction of the apparent major etiologic factors in their illnesses. The fourth (Case IV), who also had cystic lesions of the bladder at cystoscopy, is being managed conservatively without calculus removal and may possibly expect recurrent symptoms. The youngest patient was twenty-three and the oldest eighty-five years old. Three were colored females and the fourth was a white male. In only 2 cases is histologic evidence available and these are from the urethral area (Case I) and from the renal pelvic area (Case II).

REVIEW OF THE LITERATURE

The characteristics of normal and pathologic ureteral epithelium have been amply

studied. Source material has ranged from the study of a few selected pathologic specimens to large numbers of unselected autopsy cases. Many excellent reports with extensive documentation have been published. Of possible significance in our cases are the ureteral epithelial changes occurring prior to ureteritis cystica and adenocarcinoma of the ureter. Many reports of uni- and multi-cellular secretory and nonsecretory glands and crypts have been published and implicated in the etiology of these two pathologic states.

Bothe and Cristol[2] pointed out that 15 per cent of persons with frank urinary tract infection have microscopic evidence of cystic ureteral changes. Fagerstrom[4] in 1948 called attention to the important role that chronic infection and chemical irritation might have in metaplasia and gland-like changes of ureteral epithelium. He showed conclusively the increasing frequency of these changes after twenty years of age. Jacob and Mau[5] in 1951 reconfirmed the important role of chronic inflammation on a clinical and histologic basis. They could not, however, exclude developmental changes as the fundamental origin of the intestine-like epithelium found in their 2 cases.

Diverticula of the ureters may, likewise, afford some indication of the origin of the changes seen in our cases. Again, the literature is well presented and documented by several authors. Culp[3] clarified the true or congenital ureteral diverticulum as being a protrusion of the entire wall of the ureter associated with a definite stoma. A false or acquired diverticulum was defined as a protrusion of the mucous membrane through the muscular ureteral coat.

Culp[3] described 10 true diverticula as of 1947 with stomata located at the ureteropelvic junction, sacroiliac level and in the juxtavesicular segment of the ureter. He did not include bifid ureters. All but 2 of those cases had symptoms referable to the urinary tract. Pain was present in 6 and pyuria in 5. Stevens'[13] case had one diverticulum of 2 mm. and a second of apparent similar size which had ruptured. Gilmer reported a patient with a diverticulum of 6 mm. diameter, while the largest diverticulum of 19 cm. in diameter was reported by Richardson.[11]

Acquired diverticula, according to Culp, are associated with strictures, calculi or trauma, these latter most probably being of greatest etiologic importance. He concludes that congenital diverticula arise from alterations of ureteral development. These may consist of the appearance of multiple wolffian duct buds or of premature cleavage in formation of the renal pelvis. The oncology is well described by Arey[1] and Kretschmer.[7]

CONCLUSIONS

Multiple diverticula of the ureters in 4 patients have been illustrated and discussed. The possibility of their presence being artefactitious tends to be excluded by their demonstration a second time in 1 case after an interval of five years, by the fact that four different physicians performed the instrumentation for the retrograde pyelography, and by the fact that a review of the major literature fails to uncover references to similar findings by others.

Our cases strongly suggest infection as the major etiologic factor in the ureteral diverticula demonstrated. The diverticula possibly represent gland-like metaplastic epithelial response to the infection or simply pseudodiverticula on a chronic infectious basis. In Case IV the presence of cystic bladder lesions hint at some interrelationship with the ureteral changes. The associated anatomic variations in 3 of the cases, however, also suggest a possible role for developmental variation. Additional case studies, histologic inspection, and observation of the changes in the ureters over a period of time are needed for full evaluation.

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ADDENDUM

Since submission of this manuscript for publication, three additional patients with diverticular ureteral changes have been discovered. Their case histories are essentially similar to those included above. One of the new cases demonstrated ureteral changes three years prior to the recent study. No additional surgical or autopsy material has been available.

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A COMPARATIVE STUDY OF THREE INTRAVENOUS UROGRAPHIC MEDIA BY THE RANDOM SELECTION TECHNIQUE*

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TO ENABLE us to compare by statistical methods the incidence of side reactions and the quality of the pyelograms when using sodium iodomethamate (neoiopax), sodium diatrizoate (hypaque), and sodium diprotrizoate (miokon), the following study was made:† 1,468 intravenous urographic examinations were performed according to a sequence schedule set up by using "random number" tables, thereby assuring that no preselection entered into the sequence in which the three media were used and that all agents would be used under all variable conditions.

The following technique was employed routinely in obtaining the urograms: using a standard dose of 30 ml. of a 50 per cent solution of each medium for adults and approximately 0.5 ml. per kg. of body weight for children, the examiner would obtain from another member of the staff a syringe filled with one of the media along with a card bearing the patient's name. The identity of the medium, unknown to the examiner, was recorded on the back of the card. A preliminary injection of a few milliliters of the medium was given as an "intravenous test dose," a procedure of very questionable value, but one that is as satisfactory as any other when attempting to screen for sensitive individuals. If, after a few minutes no untoward reactions followed the "test" dose, the remainder of the agent was injected over a three to five minute period. After the injection, the examiner recorded any reactions that had been noted and later in the day the film quality was judged by two or more members of the staff. Films were judged "satisfactory" when the pyelogram was adequate to make a diagnosis and "unsatisfactory" when inadequate. Thus, reactions and pyelogram quality were observed and recorded in each case without the examiners knowing which medium had been used. By this method, we feel that we have pursued as unbiased a study as possible.

The "chi-square" method of statistical analysis was applied to the results. A 5 per cent "limit of probability" was used in this study. A "heterogeneity" analysis indicated that the three test groups were properly selected, were homogeneous, and that only the injected material was a significant variable.

To preserve the "blind" nature of this study, all media were injected over a three to five minute period, a technique which is against the suggestion by the manufacturer of sodium iodomethamate that it be injected within a thirty to sixty second period. For this reason, vein pain was omitted from Tables I and III. The incidence of vein pain with each medium was: sodium

TABLE I

NUMBER AND INCIDENCE OF PATIENTS EXPERIENCING ONE OR MORE REACTIONS*

Medium	Reactions	No Reactions	Total No. of Cases
Sodium Diprotrizoate	65 (13%)	424 (87%)	489
Sodium Diatrizoate	58 (12%)	425 (88%)	483
Sodium Iodomethamate	65 (13%)	431 (87%)	496

* Arm pain excluded; see text.

† The material used in this study was generously supplied by Schering Corporation, Winthrop Laboratories, and Mallinckrodt Chemical Works.

* From the Department of Surgery, Division of Urology, Washington University School of Medicine, St. Louis, Missouri.

TABLE II

QUALITY OF VISUALIZATION

	Satisfactory	Excellent	Good	Fair	Unsatisfactory
Sodium Diprotrizoate	471 (96%)	237 (48%)	160 (33%)	74 (15%)	18 (4%)
Sodium Diatrizoate	454 (94%)	213 (44%)	157 (33%)	84 (17%)	29 (6%)
Sodium Iodomethamate	429 (86%)	105 (21%)	164 (33%)	160 (32%)	67 (13%)

diatrizoate: 4 per cent; sodium diprotrizoate 5 per cent; and sodium iodomethamate 33 per cent. We feel quite certain that the higher incidence of vein pain experienced when using sodium iodomethamate was due, in great part, to the longer than recommended injection period.

There was no significant difference in the incidence of side reactions when comparing all three media. There was a significantly lower percentage of satisfactory urograms when using sodium iodomethamate than when using either sodium diprotrizoate or sodium diatrizoate. These latter two media produced a high rate of satisfactory urograms, there being no significant difference in their incidence. Tables I, II and III list the results.

TABLE III

Reaction	Sodium Diprotrizoate	Sodium Diatrizoate	Sodium Iodomethamate
Nausea	42	34	37
Nausea and vomiting	6	11	6
Flush	13	9	12
Dizziness	1	2	6
Sneezing	1	2	—
Dyspnea	2	2	1
Urticaria	4	1	—
Cough	2	—	1
Tachycardia	—	2	—
Laryngospasm	—	1	—
Cardiovascular collapse with recovery	—	—	1
Headache	1	—	1
Substernal pain	2*	—	1
Hypersalivation	1	2	—

* Both with history of angina pectoris.

SUMMARY

Sodium diatrizoate, sodium diprotrizoate, and sodium iodomethamate were compared in a series of 1,468 intravenous urographic examinations designed by the "random number" sequence technique. There was no statistically significant difference in the incidence of side reactions when comparing all three media. The incidence of vein pain was significantly higher when using sodium iodomethamate than with either of the other two media, but for reasons explained in the text, this reaction was omitted from the over-all analysis. Sodium diprotrizoate and sodium diatrizoate each produced a high rate of satisfactory urograms, the difference not being significant. However, each of these two media produced a significantly higher incidence of satisfactory urograms than did sodium iodomethamate with the technique of injection employed.

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We wish to express our sincere gratitude to Dr. Harry Morgan of the Department of Surgery, Division of Orthopedics, for his invaluable assistance both in designing this study so as to permit a statistical analysis of the results and for the performance of this analysis.

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AUTOMATIC COMPENSATION IN ROENTGENOGRAPHIC PELYCEPHALOMETRY*

By GEORGE H. BROWN, Jr.
PRINCETON, NEW JERSEY

WHENEVER a roentgenogram is made of a particular object, the resulting image is always slightly larger than the actual object under consideration. In many cases the image is sufficiently enlarged to make the usual mathematical computations necessary. This measurement problem is particularly important in the field of roentgenographic pelycephalometry. The purpose of this paper is to describe a simple, easily constructed device which will automatically and directly give a fully compensated value of a given object dimension. This particular device is designed primarily for use in roentgenographic pelycephalometry and eliminates calipers, graphs, nomograms, lengthy computations and much of the usual work necessary for roentgen image compensation. The device may be laid on the film and an automatically compensated reading is obtained directly.

The inherent image distortion is caused by the divergence of the roentgen rays and is dependent upon three factors, the anode-film distance, D, the object-film distance, d, and the object dimension, O, in question. A correction factor, a number less than unity which when multiplied by the image dimension will give the true object dimension, can be derived for a specific case when the values of D and d are known. The value of the anode-object distance is the difference between D and d.

The value of D is arbitrary and is set by the technician depending upon the limitations of his roentgen-ray machine, grid radius (if he is using a focused stationary grid), and the whims of the radiologist. The value of d can be found in a relatively simple manner, using simple arithmetic and Euclidean geometry. Thus, with a given image dimension, I, and the correction factor CF, derived in Figure 1, the true object dimension can be found.

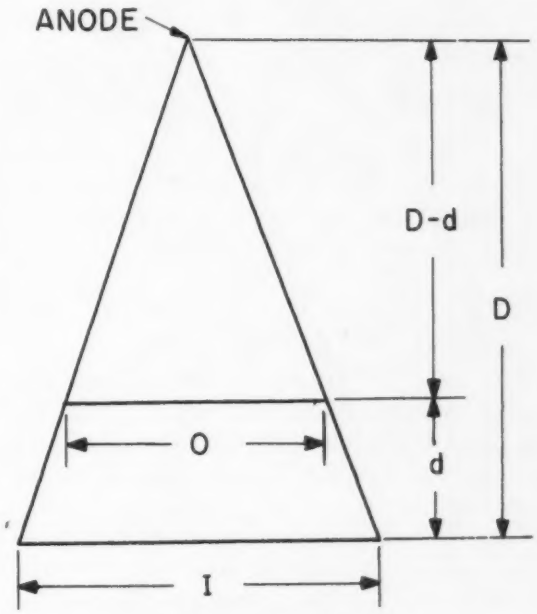

FIG. 1. By similar triangles,

$$\frac{O}{I} = \frac{D-d}{D} \qquad O = \left(\frac{D-d}{D}\right) I \qquad CF = \frac{D-d}{D}$$

Some relief from numbers may be found by means of a graph (Fig. 2) with values of D plotted as individual lines with d as the

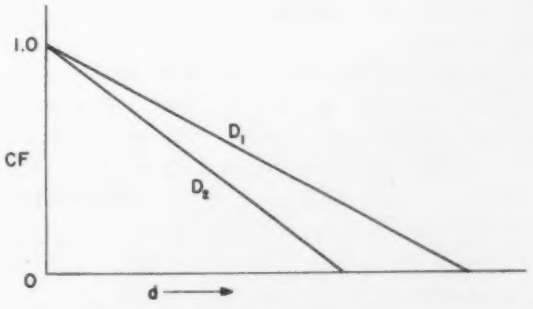

FIG. 2. A graph showing the correction factor for specific anode-film distances. As d approaches zero, the correction factor becomes unity. When d approaches D, the correction factor approaches zero.

* From the Radio Corporation of America, RCA Laboratories Division, Princeton, New Jersey.

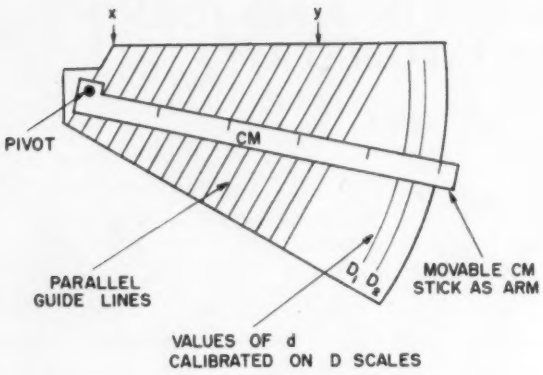

Fig. 3. Constructional principles of a pelycephalometry calculator.

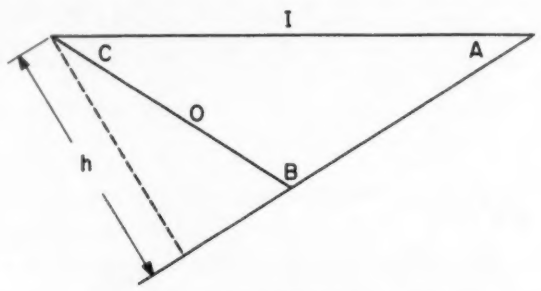

Fig. 4. Geometric principles of a pelycephalometry calculator.

abscissa and *CF* as the ordinate. The appropriate *CF* may be obtained for any value of *d* on the curve representing the correct value of *D*. For example, a particular radiologic clinic might standardize on an anode-film distance of 36 inches (91.44 centimeters).

The dimensions required in a pelycephalometry examination are generally obtained from two views, the lateral and the anteroposterior. A notched metal centimeter stick is placed in the intergluteal cleft of the patient. This puts the marker, of course, in the mid-sagittal plane of the body. All the dimensions to be measured in the lateral view lie in this plane, so the marker is enlarged in the same proportion as the dimensions. Thus, since the value of *d* is the same for all these dimensions and the marker, a particular distance to be measured may be laid on the enlarged scale and a reading obtained.

However, the dimensions in the anteroposterior view do not all lie in the same plane parallel to the film. Hence, the value of *d* is not the same in each case. A dimension in this view is seen in the lateral view as a point. The compensated length of a line through this point perpendicular to a plane representing the table top when the patient is positioned for the anteroposterior view plus the table-film distance gives the value of *d* for the particular anteroposterior dimension. Thus, the lateral view dimensions can be obtained by the marker and the anteroposterior view dimensions can be obtained by the marker plus mathematical computation or use of the device under consideration.

The correction device (Fig. 3) is constructed as a piece of plastic backing with a plastic centimeter stick mounted on it by means of a pivot at the zero point. A series of parallel lines is drawn on the backing on an angle to the horizontal so that the first one on the left intersects the pivot. As the arm is swung down, a given guide line to the right of the pivot intersects the arm at a progressively smaller value. A number of scales are drawn, one for each of the ordi-

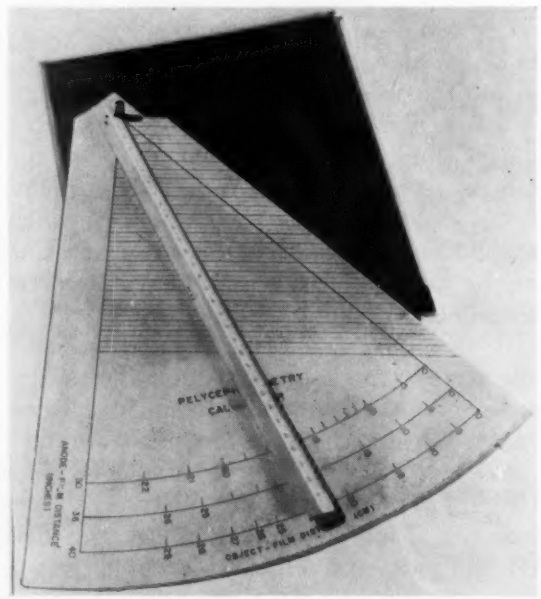

Fig. 5. A pelycephalometry calculator constructed according to the principles of this paper and using the base chart of Figure 6.

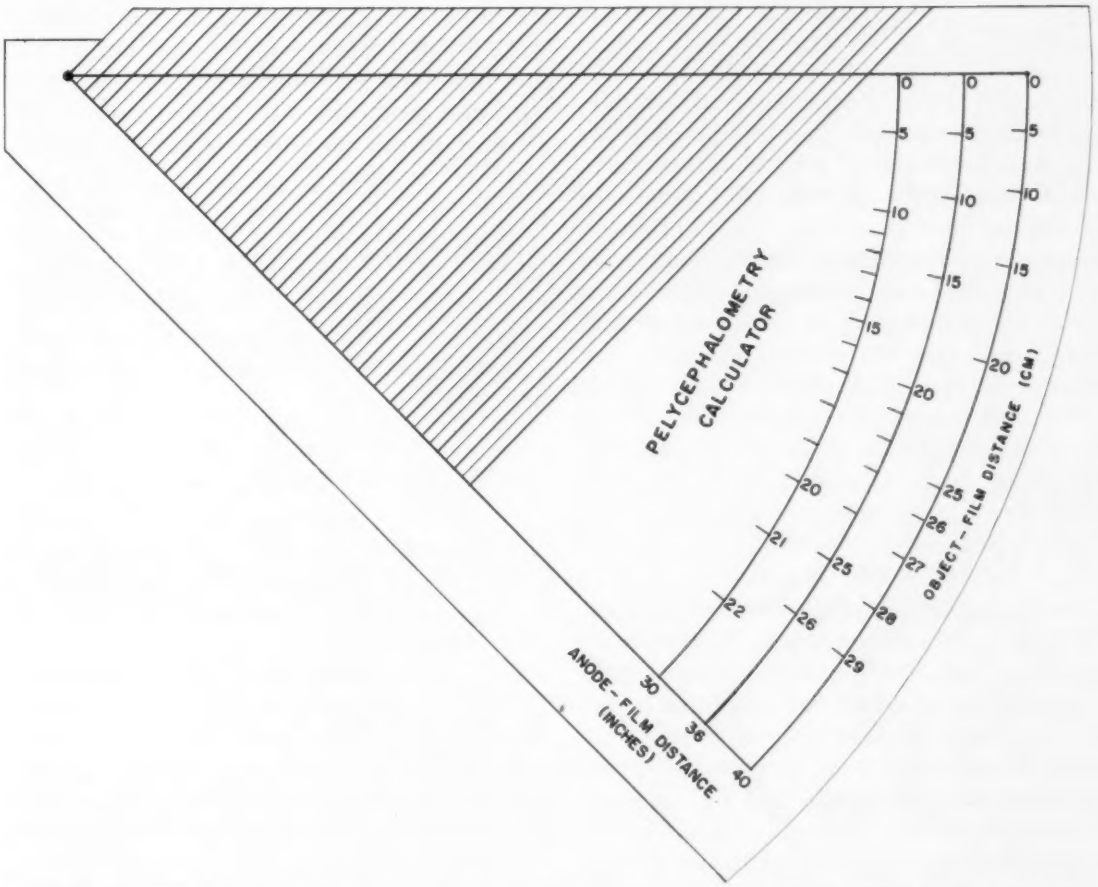

Fig. 6. A base chart for constructing a pelycephalometry calculator. (Black-line prints of this chart will be furnished by the author upon request.)

nary values of D. Each D scale is calibrated in values of d.

The angle between the parallel guide lines and the horizontal is determined by the value of the smallest CF chosen by the designer. Figure 4 shows the appropriate geometry in making this determination. Here

$$\sin B = h/O \tag{1}$$

and

$$\sin A = h/I. \tag{2}$$

Hence

$$h = O \sin B = I \sin A \tag{3}$$

and

$$CF = O/I = \sin A/\sin B. \tag{4}$$

For a given angle A, the minimum value of the correction factor CF is obtained when the angle B becomes 90 degrees (when the movable arm is perpendicular to the guide lines). In this event,

$$\sin A = (CF, \text{ minimum value}). \tag{5}$$

Once the designer has selected the smallest CF which he expects to encounter in his work, he may establish the angle A by using equation (5).

Calibration may be accomplished by means of the above equations. From equations (4) and (5), we obtain

$$\sin B = \frac{(CF, \text{ minimum value})}{CF} \tag{6}$$

or

$$\sin B = \frac{D}{D-d} \ (CF, \text{minimum value}). \quad (7)$$

Equation (7) may then be used to calculate the angle B corresponding to a given value of d on a particular D scale. A direct method of putting the appropriate values of d at the correct places on the D scales is simpler and more precise. For maximum accuracy, the extreme right guide line is used (Fig. 5 and 6). The arm is set so that it is parallel to the top edge of the back piece and the reading at the guide line is taken, representing an arbitrary value of I. Then the value of O for this I and any particular values of d and D are calculated. Next, the arm is swung down so that the line hits the scale at this calculated value of O and the calibration is made. Enough of these points are found so that interpolation is made easy and provides the necessary accuracy. When one makes the device, he must determine what the maximum value of d and the minimum value of D are likely to be. These conditions, of course, provide the maximum distortion and the smallest CF numerically.

The device is very simple to use for obtaining anteroposterior dimensions. The arm is set on the correct d value which is located on the appropriate D scale. One end of the image on the film is located at point x (Fig. 3) and the other end of the image on the film falls at some point y. Then one uses the guide lines to follow down from point y to the centimeter scale for a compensated reading.

The use of the device in pelycephalometry is perhaps only one of many. For instance, it may be of assistance in hip-pinning operations and in determination of true heart size. The device is theoretically correct and can be as accurate as one is willing and able to make it.

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NOTE ON A DARKROOM DOOR INTERLOCK SYSTEM*

By C. J. KARZMARK, Ph.D.
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A RECENT conversion to automatic film processing necessitated a door interlock system permitting entry without interfering with normal processing procedure. The system described occupies a small floor area and had functioned reliably for many months. The system consists of two doors connected by a 2½ ft. long corridor. The two doors are electrically interlocked in such a manner that when one door is opened the other cannot be opened until the first is closed. A circuit diagram appears in Figure 1. Figure 2 is a photograph of the completed installation.

One of the doors was the existing darkroom door from a hallway. The corridor consists of a 2×2 in. framework covered with plywood. It, together with the second door, was fabricated as a unit by the carpenter shop. The corridor assembly was fastened to the existing door frame and to the floor of the darkroom. For proper functioning of the interlock system it is important that the doors possess good rigidity. Some initial difficulty was experienced in the use of a low quality interior grade flush paneled door. A layer of felt or sponge rubber insures a light-tight seal of the corridor to the door frame and floor. Both doors are equipped with hydraulic closers.

The electric strikes or latch releases† are of the type commonly found on apartment house doors. They are mounted in the door jamb to replace the conventional strike plate. They must, however, be located with a ⅛ in. space between strike and latch bolt when the door is fully closed. The space is measured in the direction of door translation. The locksets employed‡ do not have knobs but are operated only with keys and/

† Trine, #2500S 8–12 V.A.C.
‡ Schlage, #B252PD.

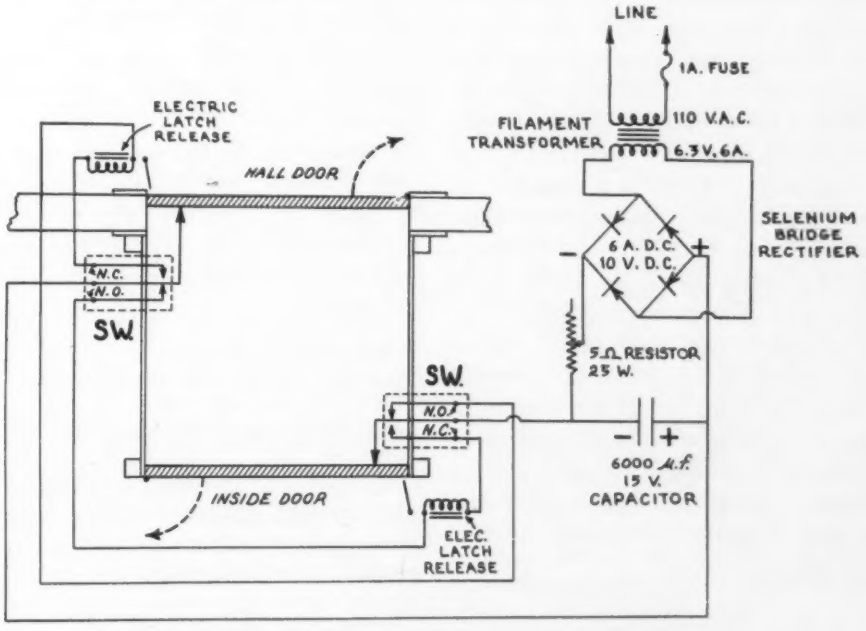

Fig. 1. A circuit diagram of the door interlock system.

* From the Department of Radiology, Stanford University School of Medicine, San Francisco, California.

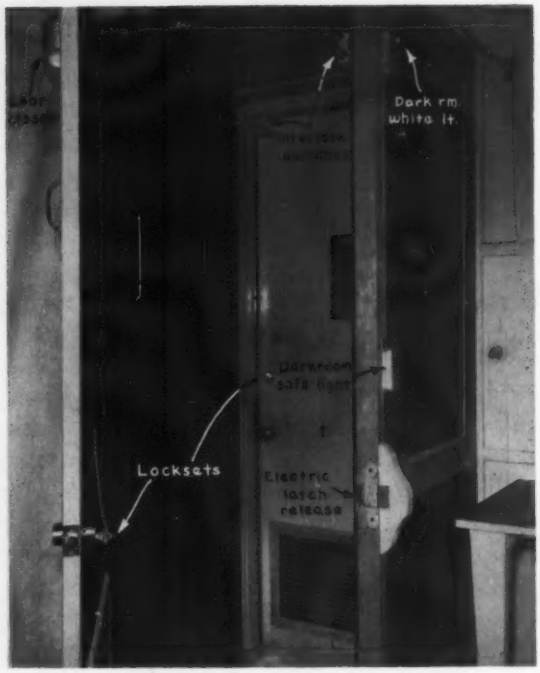

FIG. 2. Photograph of door interlock system.

or electric latch releases. For this application, the keys are normally not used. They are attached to the doors with short chains for emergency use only. The small deadlocking plungers adjacent to the latch bolts were removed. They are unnecessary for this application and may possibly interfere with normal operation. The doors are provided with a push plate and pull handle on opposite sides. Interlock switches are of the snap action type§ and are located on the top of the door jamb above the electric latch releases. Each is mounted by means of two short aluminum angle sections as shown in Figure 2. Where the angle is bolted to the switch, slots are used to provide a translational adjustment in the direction of switch plunger motion. Small metal tabs to prevent wear are fastened to the doors at the point of switch plunger contact.

The switches are positioned so that the switching action occurs when one door is opened about 1/16 in. This energizes its associated electric latch release, permitting the door to be opened further, as well as open circuiting the other electric latch release at the same instant. This permits only one door to be open at a time. A good rigid door insures that when it is given a slight translation by a pull or push near its vertical midpoint, that point of the door contacting the switch plunger, which is located near the top, is translated approximately the same distance. Note that the hydraulic door closer exerts a force which tends to nullify this relationship. This requirement could be circumvented by locating the interlock switches at the same vertical level as the push plate and door pull. However, at this location it is more difficult to prevent their becoming an obstruction for clothing, etc.

The electric latch releases are designed to operate on alternating current. They proved to be objectionably noisy when energized with alternating current, *i.e.*, door open position. A small direct current supply was constructed. This was located on the top of the corridor assembly. Operation on direct current has been quiet and reliable; no magnetic saturation difficulties were encountered with the electric latch releases. Power supply components were selected conservatively to give trouble-free performance. With one door open the variable resistor was adjusted to provide 1.5 amperes at 3 volts to the energized coil—a power adequate to give reliable operation for the particular electric latch release employed.

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§ Microswitch #BZE-2RN.

Items † and ‡ or their equivalents are available through builders hardware suppliers, while the electrical components may be obtained from electronic supply houses.

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Fortieth Annual Meeting: Hollywood Beach Hotel, Hollywood Beach, Florida, March 27–29, 1958.

EDITORIALS

FIFTY-EIGHTH ANNUAL MEETING OF THE AMERICAN ROENTGEN RAY SOCIETY

THIS year's Annual Meeting of the American Roentgen Ray Society was held at the Shoreham Hotel, Washington, D. C., October 1–4, 1957. Under the presidency of Doctor Wendell G. Scott, the meeting was one long to be remembered not only for the high caliber of the Scientific Program but for the display of scientific exhibits and the pleasant social events. The technical exhibits have not been surpassed in any of our recent meetings.

The Program was arranged by President-Elect, Doctor Wendell G. Scott and his committee, who were responsible for the excellence of the meeting.

The Scientific Session was formally opened on Tuesday morning with a call to order by President W. Edward Chamberlain, and the Address of Welcome was given by Rear Admiral Bartholomew W. Hogan (MC) USN, Surgeon General, United States Navy.

Following immediately upon the Address of Welcome, President-Elect Wendell G. Scott was installed as President. Doctor Scott was inducted into office by President W. Edward Chamberlain and the Chairman of the Executive Council, Doctor Edward B. D. Neuhauser. Doctor Scott in his Inaugural Address gave a splendid discussion on *The Emergence of the Clinical Radiologist.* Doctor Scott's address was a prologue to a group of papers dealing with a most important topic—namely, *Today's Problems in Radiation Hazards and What is Being Done About Them.* This group of papers, which are so timely and so apt in the present worldwide interest in radiation hazards, are being published elsewhere in this issue of the JOURNAL. If one wishes to familiarize himself with the present problem of radiation hazards, he need only to read this comprehensive group of papers to bring himself up to date on the subject and the precautions that must be taken in the use of all phases of radiation and the possible hazards to those who employ radiation not only for diagnostic but for therapeutic purposes as well.

On Tuesday evening the Annual Caldwell Lecture was given by Doctor Eugene P. Pendergrass, Professor of Radiology, University of Pennsylvania, School of Medicine, who was introduced by Doctor Warren W. Furey, Clinical Professor of Roentgenology, Loyola University School of Medicine, Chicago, Illinois. Doctor Pendergrass chose as his subject *Silicosis and a Few of the Other Pneumoconioses; Observation on Certain Aspects of the Problem with Emphasis on the Role of the Radiologist.* This lecture was most interesting and instructive. No one speaks with greater authority on a subject dealing with silicosis than does Doctor Pendergrass. He emphasized among other important points the role of the radiologist not only in the diagnosis of silicosis and pneumoconiosis, but the important part that the radiologist might play in the prognosis of the disease. At the completion of this address, President Scott with most appropriate and well chosen phrases congratulated Doctor Pendergrass for his great work in medicine and radiology and presented to him the Caldwell medal.

On Wednesday morning the Scientific Program of the Society was continued with an excellent group of papers dealing with

various subjects, not only on roentgen therapy but on the diagnostic problems of roentgenology. Also, on Wednesday morning there was an extensive symposium dealing with esoteric diseases of the lungs. Doctor Leo G. Rigler was Chairman of this symposium which comprised a group of papers dealing with numerous unusual and atypical diseases involving the lungs not only of adults but of children and infants. As would be expected with a symposium under Doctor Rigler's chairmanship, it proved to be most interesting and instructive.

The Scientific Program was continued on Thursday morning with a group of subjects dealing with all aspects of roentgenology, but particularly diagnostic roentgenology. Another symposium was conducted under the chairmanship of Doctor Edward B. D. Neuhauser dealing with *Benign Bone Lesions in Childhood.* This symposium was given by Doctors Caffey, Ross, Holt and Lodwick, and was devoted to the presentation of recent studies on metabolic bone disease in childhood, the recognition of certain abnormalities of the development of the hips and pelvis with particular reference to mongolism, and a discussion of the differential diagnosis of benign destructive lesions of bone. As was stated by Doctor Neuhauser in his introductory remarks, "This discussion should prove particularly valuable as rapid strides have been made in all these areas during the past few years." As prophesied by Doctor Neuhauser, the discussion was a most valuable and intensely instructive one.

On Thursday evening, cocktails in the Lower Lobby preceded the Annual Banquet, which was served in the Terrace Room of the Shoreham Hotel. At the Banquet not only were the new officers introduced to the Members of the Society, but there was presentation of the Scientific Awards. The attendance was one of the largest in the last several years, and the Banquet proved to be a most delightful and festive occasion. The floorshow itself was excellent and the opportunity for dancing following the conclusion of the Banquet made the evening a most enjoyable one.

On Friday morning the Scientific Sessions of the Society continued with a valuable group of papers dealing with radiation therapy in its various forms, together with an interesting group of diagnostic papers.

Elsewhere in this issue of the JOURNAL there is a discussion of the Scientific Exhibits and those who received the awards are listed in that discussion.

Among the guests who honored the Society by their presence were Peter J. Kerley, M.D., F.R.C.P., F.F.R., and D. W. Smithers, M.D., F.R.C.P., F.F.R. of London, England. These two distinguished radiologists not only participated in the Scientific Sessions of the Meeting but were also members of the Faculty of the Instruction Courses. The members and guests of the Society were happy to again welcome into the States Brigadier General D. B. McGrigor, O.B.E., a long time friend of many members of the Society and one who has had a notable career in the practice of radiology. He served as consultant in radiology for the British Army in the European Theatre of Operations, and has only recently retired from the regular British Army after serving forty-four years as an officer in charge of radiology. For his distinguished service during World War II and for his great assistance to American officers in the Medical Corps, particularly those in the Department of Radiology, he was awarded the American Legion of Merit.

The Instructional Courses, which over the years have been one of the important features of the Annual Meeting of the American Roentgen Ray Society, were given this year under the Directorship of Doctor Harold O. Peterson. As would be expected the various courses attracted a large group of interested individuals. Doctor Peterson had surrounded himself with a distinguished faculty of Instructors.

As is customary, adequate time was

allotted for viewing the Scientific and Commercial Exhibits.

The Scientific Exhibits, collected under the Chairmanship of Doctor John F. Holt, were intensely instructive. Doctor Holt and his committee have continued the standard for such exhibits and those who follow will find it somewhat difficult if not impossible to surpass the quality and character of the exhibits at this meeting.

Needless to say, the Technical Exhibits at this year's meeting of the Society were outstanding, both in quality and character, and there was ample room for the display of these exhibits. They attracted the attention of the members of the Society and their guests and all were praiseworthy in respect to the type and scope. This issue of the JOURNAL contains an account of the exhibits and a detailed list of the exhibitors.

The primary interest at all Annual Meetings, of course, is the Scientific Sessions, but this report would not be complete did we not call attention to the various social events which highlighted the Washington meeting. The Society is grateful to the Committee on Local Arrangements under the able Chairmanship of Doctor Edgar M. McPeak for the excellence of the social activities which had been prepared. For the visiting ladies, a fine program of entertainment had been arranged by the local Ladies Committee under the Chairmanship of Mrs. Edgar M. McPeak, consisting of a "Golf Widows" dinner, luncheon and various trips of interest throughout Washington. To this Committee and those who participated in the arrangement of the program and the splendid manner in which it was executed, the Society is very grateful and extends its profound thanks.

On Monday preceding the beginning of the meeting, the Annual Golf Tournament was held at the Manor Country Club, Norbeck, Maryland, for members of the Society and its guests. Competition in the golf tournament was for the Willis F. Manges Trophy and for the Exhibitors' Trophy. This was followed by the Annual Golf Dinner at the Manor Country Club.

To the Washington Convention Bureau, the members of the Society express their appreciation for the competent manner in which the registration at the Annual Meeting was handled.

To the Management and Staff of the Shoreham Hotel the Society has nothing but gratitude for the arrangements which were made for the meeting.

To the Committee on Press Relations under the Chairmanhsip of Doctor Ralph M. Caulk, with the assistance of Doctors Eugene McDonald and Isidore Lattman and with the splendid aid and excellent judgment of Mr. Hugh Jones of the American College of Radiology, the Society desires to express its thanks for a job well done.

As one may judge from the comments which were heard both during and after the meeting, it is the concerted opinion of those attending that the Fifty-eighth Annual Meeting of the American Roentgen Ray Society was outstanding in all respects and one that will be long remembered for its excellence.

IRA HIRAM LOCKWOOD
1885-1957

IT IS with considerable misgiving that I undertake to write this obituary for our friend and colleague, Ira Hiram Lockwood. I fear that my words are inadequate to express the measure of his life and achievements or the esteem of his friends and colleagues. Life began for Ira in Storm Lake, Iowa, November 29, 1885, where he obtained part of his schooling, graduating with a B.S. Degree from Buena Vista College. This College also gave him the honorary degree of Doctor of Science in 1956. From 1905 to 1907 he attended Iowa University and graduated in Medicine from General Medical College, Chicago, in 1909. There followed a few years of general

practice in Lincoln, Nebraska, and then World War I. In this conflict he held the rank of Major, first as Chief of the X-ray Department of Evacuation Hospital 1 AEF and later as head of the X-ray Service, 2nd Army AEF.

In 1924 he came to Kansas City to become associated with the late Dr. Edward Holman Skinner. Since then he has been Chief of Radiology at the Research Hospital and head of the Department of Radiology of Research Clinic, a venture largely accredited to him. He served as Chief of the Residency Training Program of Research, the Kansas City General Hospitals, Children's Mercy, and the Veterans Administration Hospitals of Kansas City and Wadsworth. He was also Chief Consultant in Radiology for the Veterans Administration in Missouri, Kansas, Oklahoma, and Arkansas. These were his principal positions, but in addition he himself and his teams of younger radiologists made regular circuits of some towns around Kansas City, bringing better radiology to the smaller communities.

Locally he has served as President of the Kansas City Southwest Clinical Society, Jackson County Medical Society, and has been head of the Research Hospital and Research Clinic Staffs. Nationally he was a member of the Radiological Society of North America, American Roentgen Ray Society, and was an Honorary Member of the American Radium Society. He served as President of the Radiological Society of North America and Chairman of the Board of Chancellors and President of the American College of Radiology. The latter position he held at the time of his death.

Both the American College of Radiology and the Radiological Society of North America awarded him gold medals for his contributions to radiology. His interest, however, was not limited to radiology. He was always in the forefront in civic activities and was especially active in the formation of the Blue Cross-Blue Shield plans, both locally and nationally since their inception. He was one of our most active exponents of the idea that the Medical Profession itself should put good medicine within the reach of everyone by these plans. How well he and the many others who helped start these plans succeeded is attested by the present scope of the plans themselves.

Dr. Lockwood's 81 published articles and many exhibits brought him several awards, including a Certificate of Merit from the Radiological Society of North America for a scientific exhibit on Breast Radiography. He was always interested in education and many a young man owes his start in radiology to him. He was always seeking to improve the standards of medical practice and radiology especially, becoming a Diplomate of the American Board of Radiology in 1934 and serving since the inception of this Board as Trustee and later as President and Chairman of the Executive Committee. No one was more active in examining and helping the young radiologists who sought admission to the Board than he.

Sunday, July 28, 1957 he died peacefully in his sleep, surviving his charming wife Jessie about two years. His was a life endowed with ample energy and the will and the spirit to contribute greatly in the service of mankind. He will be missed from our councils and by his host of friends.

C. Edgar Virden, M.D.

THE SCIENTIFIC EXHIBITS

The Scientific Exhibits of the Fifty-eighth Annual Meeting of the American Roentgen Ray Society, held at the Shoreham Hotel, Washington, D. C., October 1–4, 1957 were the largest and the most outstanding in the Society's history. President-Elect Wendell G. Scott and the Scientific Exhibits Committee, under the able Chairmanship of Dr. John F. Holt, have spent considerable time in preparing the necessary arrangements and their efforts have been amply rewarded by the great success of the exhibits, which also contributed so markedly to the success of this year's Annual Meeting. The exhibits were splendidly displayed encompassing the latest developments in technical, physical and clinical achievements in all branches of the science of radiology. The West Ball Room, in which they were shown, was just off the main foyer leading to the auditorium where the Scientific Sessions of the Society were held and also in close proximity to the Commercial Exhibits. That the Awards Committee must have had the greatest difficulty in making the proper selections is attested to by the fact that this year, in addition to the Silver and Bronze Medals, ten Certificates of Merit were awarded.

The following is the list of the awards.

I. Silver Medal. *A Solid-State Amplifying Fluoroscope Screen.* B. Kazan, M.A., H. B. DeVore, Ph.D., and J. Berkeyheiser, M.D., Princeton, New Jersey. In this exhibit the construction and design of a solid-state amplifying fluoroscope screen was shown and its operation demonstrated.

The panel employs two thin layers, one a CdS photoconductor and the other a Zn (S:Se) electroluminescent phosphor, with each layer in the form of plastic-bonded powder. In operation about 500 volt, 400 cycle a–c power is applied across the layers which are electrically in series. When a roentgen image excites the conductive layer, it allows a corresponding pattern of electric currents to flow through the phosphor layer resulting in an intensified visible image.

The amplifying fluoroscope was demonstrated side by side with a conventional fluoroscope screen in a shielded box. Using a common roentgen-ray source, when both screens are excited by roentgen images of equal intensity, the brightness gain of the amplifying fluoroscope and its decay characteristics are amply demonstrated.

II. Bronze Medal. *The Radiotoxic Effects of S^{35} in Growing Cartilage; Consideration of Radioactive Sulfur (S^{35}) as a Possible Radiotherapeutic Agent in Chondrosarcoma.* Philip Rubin, M.D., J. Robert Andrews, M.D., Richard L. Swarm, M.D., and Delbert M. Bergenstal, M.D., National Institutes of Health, Bethesda, Maryland. A series of experiments were performed on weaned rats using radiosulfur to evaluate the usefulness of this isotope as a possible radiotherapeutic agent in chondrosarcoma. It has been demonstrated that large doses will arrest cartilage growth without producing unfavorable systemic effects. The proximity of toxic and therapeutic doses necessarily limits its usefulness as a radiotherapeutic agent in chondrosarcoma patients.

Certificates of Merit

1. *Pulmonary Microarteriography.* A. L. Loomis Bell, Jr., M.D., Herbert F. Hempel, M.D., Seiichi Shimomura, M.D., and Eric Andreae, M.D., St. Luke's Hospital, Departments of Medicine and Radiology, New York, New York. Radiopaque material injected through a cardiac catheter wedged in a small pulmonary artery outlines the pulmonary vascular pattern.

In this exhibit this pattern was compared with the histology and hemodynamics in patients with congenital heart disease.

2. *Coronary Arteriography: A New Technique.* Charles T. Dotter, M.D., and Louis H. Frische, M.D., University of Oregon Medical School, Portland, Oregon. This exhibit demonstrated a new technique for

coronary arteriography, which was presented in detail.

3. *Chondroma of the Larynx: Roentgenologic Diagnosis; Presentation of Three Cases and Review of Literature.* Brit B. Gay, Jr., M.D., Donald R. Rooney, M.D., and Ted F. Leigh, M.D., Emory University School of Medicine, Emory University, Georgia. Chondroma of the larynx is an unusual tumor that has distinct roentgenographic characteristics. Three new cases were presented along with a review of the literature. Roentgenographic differential diagnosis was discussed and case illustrations were given.

A method of roentgenologic evaluation of the larynx employing lateral neck roentgenograms and frontal laminagrams, fluoroscopy with image amplifier and barium contrast studies of the pharynx and esophagus was also presented.

4. *Clinical Diagnostic Studies Utilizing Radioactive Isotopes.* Captain E. R. King, MC, USN, M.D., U. S. Naval Hospital, Bethesda, Maryland; Ohio State University, Columbus, Ohio. This exhibit displayed by means of art and photography highlights in the research studies and clinical use of certain radioactive isotopes, including techniques being carried on at the United States Naval Medical Center, Bethesda, Maryland.

The exhibit contained 3 units which were subtitled as follows: (a) A Comparison of Thyroid Function Studies Using Iodine 131; (b) Erythrokinetic Studies Utilizing Radioisotopes; and (c) Brain Tumor Localization by Positron Scintiscanning.

Unit (a) presented an analysis of the results of a study of the use of I^{131} in thyroid function tests. The isotope is traced through the body in the various tests. The study has indicated that a combination of the tests is necessary to adequately determine thyroid function.

Unit (b) showed graphically how three radioisotopes are commonly used in studying the erythrocyte. Vitamin B_{12}, tagged with Co^{60}, aids in the diagnosis of pernicious anemia and certain gastrointestinal malabsorption states. Cr^{51} is used to determine total blood volume and also the survival of red blood cells. Fe^{59} assists in determining the rate of utilization of iron and the rate of production of the erythrocyte. Recent advances in instrumentation make possible simultaneous determination of Cr^{51} and Fe^{59}. This allows studies of blood volume and red blood cell destruction and production to be performed on the same blood samples.

Unit (c) graphically presented a simplified radioisotopic method for brain tumor localization. The method involves two scintillation crystals connected by a coincidence circuit to an automatic scanning and printing device. Radioisotopes releasing positrons, such as As^{74} and Cu^{64} "localize" in brain tumors and are only detected in the brain when this area of radioisotope localization is between the moving scintillation crystals. Thus, the tumor, which takes up more of the radioisotope than does the normal brain, is positioned on the printed outline of the patient's head. The scan is performed one hour after the intravenous injection of a nontoxic As^{74} or Cu^{64} salt. The patient is conscious and suffers no discomfort.

5. *Capillary Bronchiolitis.* Donald A. Koch, M.D., Mercy Hospital, Port Huron, Michigan. This was a teaching exhibit. Multiple serial chest roentgenograms demonstrating changes occurring in capillary bronchiolitis were presented.

6. *Cerebral Angiography in Head Trauma; 215 Cases.* J. L. Léger, M.D., C. Bertrand, M.D., and M. R. Dufresne, M.D., Hôpital Notre-Dame, Montréal, Québec, Canada. This exhibit gave a review of technique, statistics, and roentgen findings in 215 cases of head trauma studied by cerebral angiography. These 215 cases were out of a series of 1,370 cerebral angiographic studies done from 1949 to 1956. Fifteen cases including subdural, epidural, intracerebral hematomas and other typical brain or vascular abnormalities caused by trauma were presented in detail and discussed.

7. *Primary Bone Tumors; Pattern of Bone Destruction Related to Survival.* Gwilym S.

Lodwick, M.D., University of Missouri, Columbia, Missouri. This exhibit (1) demonstrated the principal patterns of bone destruction in primary bone neoplasms; (2) showed how these roentgen patterns could be duplicated by experimental carving and drilling of normal bone specimens; (3) related the pattern of bone destruction, and other factors, such as contour and width of the margin of the destroyed area to five year survival.

8. *Intrathoracic Aneurysms in Children.* Edward B. Singleton, M.D., Dan G. McNamara, M.D., and E. Wiley Biles, M.D., Texas Children's Hospital, Houston, Texas. In this exhibit were presented various types of intrathoracic aneurysms occasionally encountered in the pediatric patient together with their roentgenologic features and methods of diagnosis.

9. *Clinical Applications of Potassium-Iodide Intensifying Screens in Contrast Media Roentgenography.* Michel Ter-Pogossian, Ph.D., and Torgny V. B. Greitz, M.D., The Edward Mallinckrodt Institute of Radiology, St. Louis, Missouri. This exhibit illustrated some clinical applications of a new type of roentgenographic intensifying screen. This screen uses thallium activated potassium iodide (KI[TI]) as phosphor. KI(TI) screens are approximately four times faster and exhibit a lower sensitivity to low energy roentgen rays than conventional ones. This increase in speed is of value in roentgenography because it allows satisfactory examinations with a considerably lower dose of radiation delivered to the patient. It also allows short exposures with low capacity roentgenographic equipment.

Potassium iodide screens are particularly useful in contrast media roentgenography because their high speed allows a considerable reduction of the roentgen-ray energy conventionally used, which results in an appreciable enhancement of the opacity of the contrast material. It was shown that the use of these screens in cerebral angiography permits satisfactory examinations with approximately one-half the amount of contrast material conventionally used.

10. *Calculation of Roentgen-Ray Dose Distribution by Using Digital Computer.* K. C. Tsien, M.A., and Robert Robbins, M.D., Temple University Medical Center, Philadelphia, Pennsylvania. The basic principles and the method of calculation involved in using a digital computer were illustrated. The dose distribution of a single roentgen-ray field was presented in tabular form as directly printed from the computing-tabulating system. By plotting the data from these, it was shown how isodose curves can be obtained.

The calculated data and published information were compared in a series of graphs. Comprehensive dose information for roentgen-ray fields of half-value layer 1.7 mm. Cu and 2.8 mm. Cu used at Temple University Hospital was presented both in tabular form and in the form of isodose curves.

Other Excellent Exhibits Were the Following:

Blood Volume Determinations; Dilution Meter Computer. Salomon N. Albert, M.D., and William A. Spencer, M.D., District of Columbia General Hospital, Washington, D. C. A plastic coil has been devised which greatly simplifies counting radioactive material in a liquid phase. A dilution computer which automatically computes dilution ratios has been constructed. This computer permits direct dilution reading of any isotope with any technique. A computer of this nature greatly facilitates and simplifies blood volume determination techniques, and makes this procedure accessible and practical for small institutions.

A cardiac output ratio (a figurative expression of the cardiac output), is obtained by injecting radioactive material into a patient, and is compared with activity eliminated into the arterial circulation by the heart over 2 units of time interval. This comparison gives an indication of the cardiac status. The result is a simple ratio obtained immediately, and could be repeated several times with each determination for blood volume.

The Absorbed Dose in Radiation Therapy: Its Measurement in Phantoms by Chemical Dosimetry and Its Importance in Clinical Radiation Therapy. J. Robert Andrews, M.D., D.Sc. (Med.), Herman Suit, M.D., and Robert W. Swain, B.S., National Cancer Institute, Bethesda, Maryland. The introduction of the rad as the unit of absorbed dose in clinical radiation therapy necessitates its experimental determination in phantoms of tissue equivalent material.

This has been achieved by the development of phantoms reproducing human anatomic parts, by the adaptation of chemical dosimetry to clinical applications and, further, by the experimental determination and analytic study of the spatial distribution of absorbed energy in these phantoms. The exhibit illustrated these several aspects of the determination of absorbed dose and the implications of the concept of absorbed dose in clinical radiation therapy.

Current Status of Intravenous Cholecystography and Cholangiography. J. Edward Berk, M.D., and Howard H. Feigelson, M.D., Sinai Hospital of Detroit, Wayne State University College of Medicine, Detroit, Michigan. The development of contrast media that may be safely administered intravenously with resultant rapid opacification of the gallbladder and extrahepatic bile ducts has opened a new field in diagnostic roentgenology. As is true of most new diagnostic procedures, that of intravenous cholecystography and cholangiography has been and will probably continue to be modified and refined. This exhibit summarized and illustrated the contrast media, the various techniques and the uses and limitations of intravenous cholecystography and cholangiography.

Angioaortography in the Diagnosis of Dissecting Aneurysms. Curtis H. Burge, M.D., Robert S. MacIntyre, M.D., and Frank M. Windrow, M.D., Methodist Hospital, Houston, Texas. Angioaortograms of patients with dissecting aneurysms, together with color photographs of the specimens, when available, were exhibited. There was a brief clinical note regarding each patient and a summary of the technique of angioaortography.

Hereditary Degenerative Osteoarthritis. William R. Christensen, M.D., and John Berghout, M.D., College of Medicine, University of Utah, Salt Lake City, Utah. This exhibit comprised a group of five cases. They represented three generations of a single family tree. With one exception the cases showed advanced degenerative osteoarthritic changes involving essentially all joint surfaces. The single exception was a younger individual who demonstrated early minimal deterioration of the hip joints occurring between the ages of fifteen and eighteen years. The history of the older cases duplicated this sequence of developing bone disease. Traumatic and occupational factors appeared to be of no importance. Serial roentgenograms of the youngest patient indicated deterioration of articular cartilage and degeneration and overgrowth of underlying bone as the basic pathology. Onset apparently was at puberty.

Radiation Therapy in Solitary Benign Cystic Bone Tumors of Children. James C. Cook, M.D., Kenneth L. Krabbenhoft, M.D., and Robert A. Songe, M.D., Harper Hospital, Detroit, Michigan. This exhibit presented cases of roentgenologically similar solitary cystic appearing benign bone lesions of children treated primarily by roentgen therapy. It included pre- and post-therapy film studies with follow-up examinations of from six to thirty years.

The conclusion was reached that conservative management by the administration of protracted small doses of roentgen therapy can produce excellent results. Extreme care in outlining treatment fields is necessary to avoid exposure of adjacent epiphyseal lines. No resulting bone damage was produced in the cases presented.

Roentgenograms and case histories of children with similar lesions treated by other methods were also shown for comparison as were representative cases of

giant cell tumors of bone in young adults managed by radiation therapy. All cases have had long term follow-up studies.

Transhepatic Cholangiography. Gerald D. Dodd, A.B., M.D., and Melvin Samuels, A.B., M.D., M. D. Anderson Hospital and Tumor Institute, Houston, Texas. It is occasionally difficult to distinguish between hepatocellular and obstructive jaundice by laboratory methods. Present cholangiographic media are of no value in the presence of clinical icterus. Percutaneous transhepatic needle puncture and opacification of the biliary radicles offer a method of differentiating the types of jaundice and establishing the location and nature of a mechanical block. The procedure is not technically difficult and entails no more risk to the patient than conventional needle biopsy of the liver.

Examples of the various types of obstruction were displayed and technique, indications, contraindications and complications of the method detailed.

Contrast Enhancement and Color Translation of X-ray Films with Television Techniques. J. F. Fisher, B.S., and J. Gershon-Cohen, M.D., Department of Radiology, Albert Einstein Medical Center (Northern Division), Philadelphia, Pennsylvania. A technique was illustrated by which the contrast may be enhanced on roentgenographic films and translated into color, using television methods. Films were shown to demonstrate the advantages of this procedure as well as to point out the difficulties and limitations of the method.

Simultaneous Multisection Laminagraphy in Practice. Kamillo Flachs, M.D., and Philip D. Masters, R.T., Veterans Administration Hospital and University of Buffalo Medical School, Buffalo, New York. The exhibit presented the practical applications of simultaneous multisection laminagraphy.

Roentgenography of the Breast. J. Gershon-Cohen, M.D., Victor Kremens, M.D., Simon M. Berger, M.D., and Helen Ingleby, M.D., Albert Einstein Medical Center (Northern Division), Philadelphia, Pennsylvania. Experience with approximately 4,500 roentgenographic breast studies over a period of eight years has proved the merit of this type of examination. The method is particularly useful in evaluation of the "lumpy" breast, in detection of occult lesions and as an aid in differentiation between benign and malignant disease prior to surgical intervention. Pathologic correlation has been entirely in keeping with results obtained in other areas of roentgen diagnosis.

The exhibit included roentgenograms of the normal breast, benign breast conditions, and malignant disease. Diagnostic criteria for differentiation between benign and malignant disease were stressed.

Nitrous Oxide Insufflation for Soft Tissue Diagnosis. David M. Gould, M.D., and James W. Buice, M.D., University of Arkansas School of Medicine, Little Rock, Arkansas. Insufflation of the soft tissues with rapidly absorbing nitrous oxide provides an ideal contrast medium. Many of the potentialities of this procedure were demonstrated.

Normal Roentgen Anatomy of the Thorax. Floyd E. Hawes, M.D., The Faulkner Hospital, Jamaica Plain, Boston, Massachusetts. Four models for teaching roentgen anatomy accurately and rapidly to medical students, residents, and graduate physicians have been originated by the author. Each model can be constructed by the student in one session of sixty to ninety minutes from inexpensive and readily available materials. Roentgenographic films were also exhibited as they are used during the teaching sessions before each model is constructed. The models are: (1) A pair of styrofoam seven-inch "lungs" cut into 20 segments and re-assembled; (2) complete bronchial tree constructed from translucent tubing and correct as to length and diameter; (3) mediastinal structures to scale and enclosed in a translucent eight-inch box; and (4) plaster of Paris heart and great vessels with coronaries outlined by the student.

Roentgen Manifestations of Acute Leu-

kemia. Theodore F. Hilbish, M.D., Byron E. Besse, Jr., M.D., Lee B. Lusted, M.D., and Louis B. Thomas, M.D., Department of Health, Education and Welfare, Public Health Service, National Institutes of Health Clinical Center, Bethesda, Maryland. This exhibit demonstrated the roentgenologic changes resulting from acute leukemia. Emphasis was placed upon the gross, microscopic and pathologic findings in bone as related to the roentgen manifestations.

Gliomas of the Optic Nerve. C. B. Holman, M.D., H. W. Dodge, Jr., M.D., J. G. Love, M.D., M. B. Dockerty, M.D., A. B. Hayles, M.D., T. P. Kearns, M.D., and W. McK. Craig, M.D., Mayo Clinic, Rochester, Minnesota. Gliomas of the optic nerve are slow-growing neoplasms that may arise in the optic nerve, optic chiasm or optic tract.

Symptoms produced by gliomas of the optic nerve are caused by destruction of the visual pathways or by pressure of the enlarging tumor on surrounding structures in the orbit or cranial cavity.

Early recognition of these tumors is of great importance because localized lesions in favorable sites are notably curable by surgical excision.

This exhibit dealt with clinical symptoms, ocular manifestations, roentgenologic signs, pathologic features and surgical treatment.

Dosage Distributions for Various Loadings of the Ernst Radium Applicator. Jack S. Krohmer, M.A., School of Medicine, Western Reserve University, Cleveland, Ohio. A series of charts for commonly used loadings of the Ernst applicator giving dose to Point A, Point B, and cervix was displayed. Also a complete chart for simple calculation of dosage distribution for any loading of the applicator was exhibited.

Hobby Horse Cassette Holder. Colonel Elmer A. Lodmell, MC, M.D., and M/Sgt. Russell P. Rankin, Walter Reed Army Hospital, Washington, D. C. This exhibit presented the Hobby Horse Cassette Holder and demonstrated its use.

The Roentgen Findings in Lymphosarcoma of the Small Intestine. Richard H. Marshak, M.D., Bernard S. Wolf, M.D., and Joan Eliasoph, M.D., The Mount Sinai Hospital, New York, New York. With increasing experience with small intestinal lymphosarcoma as well as the recognition of the abnormal patterns produced by other small intestinal ailments, it has become apparent that primary lymphosarcoma of the small bowel often presents an appearance which is highly suggestive of the underlying pathologic alterations. The differences in the roentgen changes produced are primarily a function of the direction of growth and multiplicity of lesions. A classification of these roentgen changes was given and illustrated. They include: (1) Predominant invasion of the mesentery; (a) large extraluminal masses, (b) production of the sprue pattern. (2) Polypoid form (intussusception). (3) Infiltrating form. (4) Multiple small nodular defects. (5) Endo-exo-enteric form with extensive excavation, perforation and fistula formation.

Low Intensity Radium Needle Therapy. Charles L. Martin, M.D., and James A. Martin, M.D., Martin X-Ray & Radium Clinic, Dallas, Texas. Dosage calculations, techniques and statistics were illustrated with charts, diagrams and tables and clinical results were depicted in large dye transfer prints in color.

Segmental Motor Paralysis; Mechanical Intestinal Obstruction Without Physical Block. Thomas F. Meaney, M.D., and C. Robert Hughes, M.D., Cleveland Clinic Foundation, Cleveland, Ohio. Surgical exploration of the abdomen sometimes fails to confirm the presence of a mechanical intestinal obstruction when typical clinical and roentgenologic manifestations are present. A concept was set forth which may explain this lack of correlation in some patients. The explanation was based on the fact that lack of effective peristalsis in a segment of intestine may result in intestinal obstruction. The obstruction is of the mechanical type despite the fact that no

physical agent occludes the lumen of the intestine.

Illustrative cases were presented.

Roentgenographic Chest Findings following Chest Surgery. Myron Melamed, M.D., Hiram T. Langston, M.D., and Anton M. Pantone, M.D., University of Illinois College of Medicine and Chicago State Tuberculosis Sanitarium, Chicago, Illinois. The material presented depicted the normal and abnormal roentgenographic findings involving the chest, following chest surgical procedures. Cases studied were patients subjected to chest surgery because of pulmonary tuberculosis or associated diseases. They comprised approximately 350 in number.

Illustrative cases have been carefully selected to demonstrate various postoperative changes.

Improved Technique of Peripheral Arteriography. J. E. Miller, M.D., A. D. Sears, M.D., and R. E. Collier, M.D., Baylor Hospital, Dallas, Texas. An improved technique was presented for use before vascular surgery. It permits visualization of the lower portion of the aorta, its bifurcation and the peripheral branches as far as the lower margin of the popliteal space. Principal factor allowing such excellent visualization throughout widely varying soft tissue parts results from use of a large Bucky diaphragm which is completely portable and a wedge filter.

Roll Film Device for the Index for Roentgen Diagnosis. Theodore J. Pfeffer, M.D., St. Francis Hospital, Milwaukee, Wisconsin. A motor-driven roll film device for quick reference to the Index for Roentgen Diagnosis was presented. The Index was copied and reprinted on roll film eleven inches in width. Each page of the Index appears under the viewing aperture as desired by rolling the film forward or backward. The viewing aperture is 8×10 inches in dimension. The film is viewed by direct light. The electric motors operate on standard 110–115 a.c. current. The presently designed unit is housed in a metal shell, the dimensions being: width 15 inches, length 15 inches and height 10 inches.

Fractures of the Calcaneus. Arnold D. Piatt, M.D., Gerald A. Erhard, M.D., and William V. Banning, M.D., Newark, Ohio. Fractures of the calcaneus are the most common fractures of the tarsal bones and the over-all poor results are to some degree influenced by the roentgenographic interpretations and examinations. The technique of the examination as well as a simple classification and the various types of fractures were shown. The so-called "recoil" type of effect was demonstrated.

Transverse Laminagraphy—a Third Dimension in Roentgenography; Applications in Diagnosis and Therapy. Bernard Roswit, M.D., Sol M. Unger, M.D., Stanley J. Malsky, M.A., M.Sc., and Cyprian B. Reid, B.Sc., Veterans Administration Hospital, New York (Bronx), New York. Transverse laminagraphy provides a third dimension in roentgenologic diagnosis and therapy. Living cross-sections of the body yield valuable anatomic and pathologic data not accessible by any other procedure.

This exhibit presented the authors' experience of the past three years with this technique in a large variety of roentgen diagnostic problems. Particularly in the head, neck and thorax has transverse laminagraphy been helpful In radiation therapy these living cross-sections have been especially valuable for tumor localization and treatment planning.

Knee Trauma Demonstrable in Pneumoarthrography. Maurice D. Sachs, M.D., and Wilbert H. McGaw, M.D., Veterans Administration Hospital, and Western Reserve Medical School, Cleveland, Ohio. Pneumoarthrograms of the knee joint were shown depicting primarily trauma, that is, various types of tears of the medial and lateral menisci, quadriceps adhesions, rupture of the patellar tendon, etc. A normal pneumoarthrogram, with all of the soft tissue structures, was included as a guide.

Vascular Groove Simulating Skull Fracture. Forrest V. Schmacher, M.D., and Gregory T. Henesy, M.D., Radiological

Clinics of Drs. Groover, Christie and Merritt, Washington, D. C. An inconstant vascular groove in the squamous portion of the petrous bone should be recognized as a normal variant rather than a fracture. Study of skull specimens revealed this vessel to be a nutrient artery arising as a branch of the middle meningeal artery. The roentgenographic appearance of the nutrient vessel and its differentiation from a fracture was shown in detail. The incidence of this variant in 996 skull examinations was given.

Nonmalignant Vertebral Sclerosis Simulating Neoplasm. Gerhart S. Schwarz, M.D., and Wolfgang Ackermann, M.D., Presbyterian Hospital, New York, New York, and Francis Delafield Hospital, New York, New York. Vertebral body biopsies were performed on 339 cancer patients and one cancer suspect at the Delafield Hospital by one of the authors (W. A.) in search for metastases. In 28 cases sclerosis was shown histologically yet in 13 the absence of cancer cells was demonstrated microscopically at the same time in the affected vertebra. In 5 of the 13 cancer-free persons vertebral sclerosis was revealed on roentgenograms, also leading to the erroneous roentgen diagnosis of metastasis. In 1 of the 5 cases the benign nature of the vertebral sclerosis was reaffirmed later by an autopsy.

Five additional cases of vertebral sclerosis were detected roentgenographically at the Presbyterian Hospital in young to middle aged adults who sought medical advice for backaches. At first a metastasis was suspected, but finally a disk prolapse was diagnosed clinically at the interspace adjacent to the area of sclerosis. Documentation of the disk lesion varied in this group but in one instance disk prolapse was confirmed by myelography, laminectomy and cessation of complaints after removal of the prolapsed portion of the disk, whereas the benign nature of the sclerosis was suggested by a continued benign course and a (not very adequate) curettement of the sclerotic vertebra through its circumferential cortex.

Roentgenograms, photomicrographs and histories of malignant and nonmalignant vertebral sclerosis were displayed and the trephine instrument designed and used by one of the authors (W. A.) for vertebral biopsy was shown.

The conclusion was reached that nonneoplastic circumscribed vertebral sclerosis can appear in cancer patients and those who are free of malignancy alike. In a small number of cases disk disease may have been the cause, the association of localized vertebral sclerosis with disk disease first having been demonstrated by Schmorl.

The LogEgram. Elmer G. St. John, M.D., and Dwin Craig, B.S., Binghamton City Hospital, Binghamton, New York. The LogEgram is an automatically dodged roentgenogram by electronic methods. By this procedure it is possible to enhance otherwise invisible or poorly visualized roentgenographic images.

The procedure was illustrated in detail.

Roentgenographic-Pathologic Correlation of Gallbladder Tumors. John H. Walker, M.D., and Hugh W. Jones, M.D., Mason Clinic, Seattle, Washington. Small intraluminal tumors of the gallbladder are variable in clinical import and histologic diagnosis. This exhibit gave a workable histopathologic classification and illustrated the roentgen criteria that offer assistance in differentiating the significant from the unimportant lesion. Examples of each lesion were illustrated by roentgenograms, color photographs of gross specimens and photomicrographs.

Photoscanning, I^{131} Uptake and Sample Counting with a Single Unit. Walton D. West, M.S., Vincent P. Collins, M.D., and C. T. Teng, M.D., Baylor University College of Medicine and Jefferson Davis Hospital, Houston, Texas. When a radioisotope is administered, it is desirable to know the site of localization and the amount deposited. Additional information is gained from a pictorial record which shows the size and shape of the area of radioactivity. This is commonly obtained by scanning the region with a closely collimated detector and

producing an image by an ink recording system on paper.

The instrument shown in this exhibit uses a light beam to record the image of the radioactive area within the patient on roentgenographic film which is simultaneously exposed for a conventional roentgenogram of the region. The unit can be expanded to do I^{131} uptake and sample counting by adding scaling strips and timer.

Reduction of Radiation Hazard in Obstetric Roentgenography. Walter M. Whitehouse, M.D., Charles S. Simons, Ph.D., and Tommy Evans, M.D., University Hospital, Ann Arbor, Michigan. There is increasing concern in both scientific and lay circles about dangers of exposure to radiation. A portion of this concern deals with medical roentgenographic use, and this has been of particular concern when both mother and fetus are examined. While acknowledging that the ultimate genetic effect of diagnostic radiation cannot be determined in the near future, we must be in a position to assure our consultants and patients that every effort is being made to reduce the radiation to which the mother and fetus are exposed.

Five approaches to the reduction of radiation were presented and illustrative cases were shown. These were: (1) Roentgenography only for significant clinical indication; (2) simplification and standardization of obstetric roentgenography; (3) adequate aluminum filtration with supplementary wedge filter; (4) use of newly available fast film; and (5) use of fast screens, with planned use of faster screens as they become available.

Axial Transverse Laminagraphy of the Chest. Stefan P. Wilk, M.D., University of California, Los Angeles, California. This exhibit included: presentation in form of diagrams of the general principles of axial transverse laminagraphy and its potentialities; illustration by diagrams and examples of practical aspects; and finally a presentation of a few cases of axial transverse laminagrams of the chest.

Motor Phenomena in the Distal Esophagus; Diagnosis of Minimal Hiatal Herniation. Bernard S. Wolf, M.D., Richard H. Marshak, M.D., Max L. Som, M.D., and Sigmund A. Brahms, M.D., The Mount Sinai Hospital, New York, New York. This exhibit presented, in a motion picture, the intrinsic functional phenomena in the distal esophagus and esophagogastric region. Roentgen evidence for the existence of the inferior esophageal sphincter and the vestibule of Lerche was demonstrated in patients with small hiatus hernias.

Since a portion of the vestibule normally lies within the diaphragm and abdomen, it is not possible to visualize the vestibule completely without some degree of hiatal herniation. By the same token, visualization of the complete vestibule above the diaphragm is indicative of minimal hiatal herniation.

The suggestion was made that the terms vestibule and phrenic ampulla are not to be used synonymously since they apply to different phenomena.

THE COMMERCIAL EXHIBITS

To have viewed the Commercial Exhibits of the Fifty-eighth Annual Meeting of the American Roentgen Ray Society, held at the Shoreham Hotel, Washington, D. C., October 1–4, 1957 was a striking experience. The excellent facilities at the Hotel, the spaciousness of the room and, most of all, the beautiful and artistic displays of the individual exhibits were contributing factors to the over-all success of the Meeting. The many new aids to radiologists which the exhibitors presented brought forth enthusiastic interest from those attending the exhibits. A great deal of time-consuming work on the part of Mr. Clifford L. Sherratt, Honorary Member, and Dr. James C. Cook, Manager of the Annual Meeting, was evident; however, judging by the attention that the Commercial Exhibits attracted, these efforts were most worthwhile. The Society extends to all exhibiting firms its profound thanks and appreciation.

The following is a list of the firms which participated in the Commercial Exhibits:

Abbott Laboratories, North Chicago, Illinois; Ansco, Binghamton, New York; Atomic Energy of Canada Limited, Ottawa, Ontario, Canada; Automatic Seriograph Corporation, College Park, Maryland; Barnes-Hind Barium Products Company, Sunnyvale, California; Bar-Ray Products, Inc., Brooklyn, New York; Bell-Craig, Inc., New York, New York; Blair X-Ray Inc., Los Angeles, California; Carr Corporation, Culver City, California; Dick X-Ray Company, St. Louis, Missouri; Dunlee Corporation, Chicago, Illinois; E. I. du Pont de Nemours & Company, Wilmington, Delaware; Eastman Kodak Company, Rochester, New York; Eureka X-Ray Tube Corporation, Chicago, Illinois; Fairchild Camera and Instrument Corporation, Jamaica, New York; E. Fougera & Company, Inc., Hicksville, L. I., New York; F-R Machine Works, Inc., Woodside, New York; Franklin X-Ray Corporation, Philadelphia, Pennsylvania; General Electric Company, Milwaukee, Wisconsin; Gray Pharmaceutical Company Inc., Newton, Massachusetts; Grune & Stratton, Inc., New York, New York; Halsey X-Ray Products, Inc., Brooklyn, New York; Ilford Inc., New York, New York; Keleket X-Ray Corporation, Walton, Massachusetts; Leishman X-Ray Engineering Company, Los Angeles, California; Liberty Protective Leathers Inc., Gloversville, New York; Liebel-Flarsheim Company, Cincinnati, Ohio; LogEtronics Inc., Alexandria, Virginia; Low X-Ray Film Corporation, New York, New York; Machlett Laboratories, Inc., Springdale, Connecticut; Mallinckrodt Chemical Works, St. Louis, Missouri; Mattern X-Ray Division, Land-Air Inc., Chicago, Illinois; Donald McElroy, Inc., Chicago, Illinois; Medical Case History Bureau, New York, New York; Micro X-Ray Recorder, Inc., Chicago, Illinois; Mid-West Glove Company, Inc., Chicago, Illinois; C. V. Mosby Company, St. Louis, Missouri; North American Philips Company, Inc., New York, New York; Pako Corporation, Minneapolis, Minnesota; Physicians' Technical Equipment Company, Milwaukee, Wisconsin; Picker X-Ray Corporation, White Plains, New York; Schick X-Ray Company, Inc., Chicago, Illinois; Frank Scholz X-Ray Corporation, Boston, Massachusetts; Siemens New York Incorporated, New York, New York; Standard X-Ray Company, Chicago, Illinois; Charles C Thomas, Publisher, Springfield, Illinois; United States Radium Corporation, Morristown, New Jersey; Victoreen Instrument Company, Cleveland, Ohio; Westinghouse Electric Corporation, Pittsburgh, Pennsylvania; Winthrop Laboratories, New York, New York.

BOOK REVIEWS

Books sent for review are acknowledged under: Books Received. This must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interest of our readers as space permits.

MEDIZINISCHE RÖNTGENTECHNIK. I. MEDIZINISCHER TEIL. SKELETTAUFNAHMEN UND ORGANUNTERSUCHUNGEN. By Prof. Dr. Herbert Schoen, Karlsruhe. Dr. Detlev Schoen, Marburg/Lahn. Price, DM 29.70. Pp. 347, with 534 illustrations. Georg Thieme, Herdweg 63, Stuttgart, Germany, 1956. (For sale in the United States and Canada by the Intercontinental Medical Book Corporation, New York 16, New York.)

This is a beautifully and adequately illustrated textbook on the technique of roentgenography. The author has combined illustration of specimens of human skeletal parts with the photographs of the various positions, together with the resulting roentgenograms.

In this second and enlarged edition, the authors have added chapters on soft-tissue diagnosis and the various later developments of the diagnostic uses of contrast materials, as well as body section roentgenography in the study of the blood vessels particularly. Vasography and pneumoradiography, the latter especially by the method of intra- and retroperitoneal gas insufflation, have been described at length. Several new devices have been added to foreign body localizations. The technique of enlargement of the roentgenograms has also received special attention.

Even without a knowledge of German, any intelligent technician would find important help in this work. It is full of new ideas.

JAMES T. CASE, M.D.

I QUADRI RADIOLOGICI DELLE GASTRITI. Relazione al LVII Congresso della Società Italiana di Medicina Interna, Milano—Ottobre 1956. By Prof. Alessandro Vallebona, with the collaboration of Prof. Luigi Oliva. Paper. Pp. 83, with 31 illustrations. Ditta Luigi Pozzi, Editore, Via Sistina 14, Rome, Italy, 1956.

This book was prepared by the authors to present a roentgenologic study of gastritis to the 57th meeting of the Italian Society of Internal Medicine.

Professor Vallebona has been interested in study of the fine detail of the gastric mucosa for many years and has pioneered in the use of gastric double contrast. The authors describe minutely all forms of gastritis and quote the extensive literature on this subject as well as their own experience in the roentgenologic field.

The summary and conclusions of this book are particularly interesting because the authors state that roentgenologic studies are inconclusive in the diagnosis of gastritis, and that their main function is to exclude ulceration and neoplastic disease. Such conclusions are refreshingly honest and are especially valuable because they come from workers who know their subject very thoroughly not only from the viewpoint of roentgenology but also from that of endoscopy, pathology and surgery.

CESARE GIANTURCO, M.D.

THE SPINE; ANATOMICO-RADIOGRAPHIC STUDIES, DEVELOPMENT AND THE CERVICAL REGION. By Lee A. Hadley, M.D., Senior Attending Roentgenologist, Syracuse Memorial Hospital; Clinical Associate Professor of Public Health, New York State College of Medicine; Consultant in Radiology, Syracuse State Medical School, Syracuse, New York. Cloth. Price, $6.50. Pp. 156, with numerous illustrations. Charles C Thomas, Publisher, 301 East Lawrence Avenue, Springfield, Illinois, 1956.

This very interesting monograph, subtitled "Anatomico-Radiographic Studies, Development and the Cervical Region", is a remarkable correlation of gross and microscopic anatomy with roentgenographic findings of the cervical spine. It should dispel the general misconception of arthritis by its clear differentiation of bone changes resulting from congenital variations from those of traumatic origin and those resulting from the wear and tear of advancing age.

The author does not attempt to present a thorough discussion of fractures and dislocations, but is concerned with subluxations of the cervical spine, together with the resultant angulation and the protective response of the bone tissue which produces eburnation and osteophyte formation. A short study of the development of the spine is included to furnish an understanding of the origin of many abnormal

changes which are frequently encountered in the roentgenographic examination in the cervical region. Some practical suggestions are made regarding the roentgenographic technique for study of the cervical spine and the various projections are well illustrated depicting the specific advantage of each view. Of particular interest are the roentgenograms of patients examined at or near the time of injury, and whose clinical course was followed by anatomic studies or by checkup roentgenograms demonstrating the post-traumatic changes many years later.

K. K. Latteier, M.D.

Positioning in Radiography. By K. C. Clark, M.B.E., F.S.R., University of London, British Postgraduate Medical Foundation. Seventh edition. Cloth. Price, $29.00. Pp. 655, with 2,150 illustrations. Intercontinental Medical Book Corp., 381 Fourth Avenue, New York 16, New York, 1957.

This well known English text which has been an outstanding book in every respect was originally published in 1939. There have been six editions since then, the present volume being a revision of the last edition which was published in 1951. The numerous advances in radiography are adequately incorporated in this 7th edition to bring it into line with modern radiographic practice. Those who are acquainted with this book will recognize it as a valuable text on radiographic positioning, with wide scope and fine illustrations, making it as complete as is practical in a single volume.

The book has been increased by over 100 pages and 600 new illustrations, bringing the total number of illustrations to 2,150. Many of the previous illustrations have been revised. They are of excellent quality and the reproduced roentgenograms very nearly approach the clarity of the originals. White lines have been drawn on some of the photographs to indicate the direction of the central ray. The peripheral ray is also illustrated in many instances. Black spots have been placed on the subject and on the radiographs to indicate the tube centering point. Line diagrams and explanatory charts are used in appropriate places. The Birmingham revision (1933) of the anatomic terminology is used, but some of the older terms are shown in brackets where common use has made them popular. For each position shown, complete exposure data are given, namely: kilovolts, milliampere seconds, focus film distance, intensifying screens employed, localizing cones, type of grid when used, and size of film. Exposures in each instance are intended for a subject of average size, but may be adjusted to the individual patient in any similar investigation. Where multiple projections or various methods can be used, alternative exposures are also indicated, thus providing the technician with a choice of numerous variations in technique. Special techniques are given for children and variations in technique are included to accommodate the acutely ill as well as ambulatory patients. This book also deals with techniques used in the various specialized fields, covering almost all known radiographic procedures. Exposure factors have been corrected for the use of modern high kilovoltage equipment. Sections have been added on macroradiography, angiography, cerebral angiography, and the use of contrast media in special procedures. Miniature radiography and cineroentgenography are also considered.

There is a new supplement on radiation exposure of the patient and a very complete index where subject material has been made readily accessible under anatomic, pathologic, and physiologic terms. The book does not discuss physics or electric equipment although the use of various accessories with special techniques is mentioned. There is adequate anatomic description, but there is no attempt to interpret the roentgenograms. The main purpose is to provide a systematic method of procedure and technique, bearing in mind the fundamentals of positioning. This purpose is admirably accomplished.

K. K. Latteier, M.D.

Guide to Medical Writing; A Practical Manual for Physicians, Dentists, Nurses, Pharmacists. By Henry A. Davidson, M.D., Editor, Journal of the Medical Society of New Jersey. Cloth. Price, $5.00. Pp. 338. The Ronald Press Company, 15 East 26th Street, New York 10, New York, 1957.

The art of medical writing is much neglected. The busy practicing physician has usually forgotten his college course in English composition and needs help badly on the many occasions when he must express his thoughts in writing.

The author of this book is an experienced writer and editor. His advice in preparing, organizing and concluding a medical article is practical and the book is readable. Many examples are given of common errors which cause a quivering of the editor's blue pencil; better

wording is explained in detail. The final chapter, listing all the leading journals in medical fields, seems superfluous until we consider that the book is written for dentists, nurses and pharmacists as well as for physicians. The chapter including conversion tables of weights and measures and sections about eponyms and prescriptions contains much practical information. There is also an excellent chapter dealing with illustrations and graphs. The book has a good index.

This book is a valuable contribution to the important, but rather neglected field of medical writing.

Robert E. Fricke, M.D.

Rectoscopie, Sigmoïdoscopie. By P. Hillemand, R. Cattan, A. Lambling, and A. Bensaude. Third edition. Cloth. Price, 7,400 fr. Pp. 270, with 127 figures and 39 color plates. Masson et C^ie^, Éditeurs, 120 boulevard Saint-Germain, Paris 6^e^, France, 1956.

This book, originally published in 1926, has been out of print for many years. During the past thirty years considerable additional information on rectal pathology has become available. In this third edition some of the original chapters have been completely modified—many diseases commonly encountered at that time are now seldom seen, due to modern therapeutic methods; and our knowledge of the rare diseases has also increased greatly. Most of this new edition has been devoted to rectosigmoidoscopy. The authors, pupils of the late Bensaude, in their revision followed the general outline of the first edition but have also added important chapters covering the recent acquisitions in this field. The new therapeutic procedures, utilizing endorectoscopy as a guide, have been made more precise, especially contact radiation therapy. The chapter on hemopathies is completely new and has not been published elsewhere.

Forty new aquarelles taken from the collection of Bensaude and the recent authors have been added to the beautiful iconography of the original edition. The number of black and white illustrations has been increased—reproductions of roentgenograms and photographs of gross specimens and microscopic sections are well correlated with the findings of the endoscopic examination. There are 39 color plates depicting normal structures and pathologic lesions as found by inspection and at endoscopy which would constitute a magnificent atlas if published separately. This collection is especially helpful for teaching purposes. The legends facing each plate are in French, English, Spanish, German, Italian and Portuguese.

The book is a masterful synthesis on the subject of primary and secondary diseases of the rectosigmoid. It is a valuable text or reference book for surgeons and gastroenterologists interested in the pathology of the terminal colon. It offers a fair appraisal of the possibilities and limitations of digital, roentgenologic and endoscopic methods for proper diagnosis with special emphasis on endoscopic examinations. It contains a concise discussion of the pathology and pathogenesis of each disease. It stresses the practical and prognostic importance of differentiating neoplastic polyps with malignant potentialities (adenomas, villous polyps or papillomas, adenopapillomas) from hyperplastic polyps such as the inflammatory type encountered in children and the types found in ulcerative and dysenteric colitis.

A criticism of secondary importance is the brief bibliography.

Henri Paul Levesque, M.D.

Études sur la Précision en Radiodiagnostic. Techniques d'un Nouveau Craniographe. Notation Angulaire de l'Incidence. By G. L. Dulac, Ancien chef de service à la Fondation Curie. Paper. Price, 1,300 fr. Pp. 134, with 47 illustrations. Masson et C^ie^, Éditeurs, 120 boulevard Saint-Germain, Paris 6^e^, France, 1956.

This monograph deals with a new type of apparatus designed particularly for cranial roentgenography. The apparatus permits various forms of angulation, stereoscopy and laminagraphy and has a flexibility which enables one to alter relationships of anatomic parts to the film for selective enlargement or studied blurring. Actually, the "craniograph" is not unlike other especially devised apparatus intended for all forms of cerebral roentgenography.

The author seeks to develop roentgen techniques which stem from carefully selected angulation of apparatus with reference to the head; indeed, this factor seems oversimplified and would lead the experienced individual to question some of the claims made for the "craniograph."

Philip J. Hodes, M.D.

Technique du Radiodiagnostic. By J. Garcia-Caldéron and G. Ledoux-Lebard. Second edition. Cloth. Price, 7,800 fr. Pp. 1,148,

with 746 illustrations. Masson et Cie, Éditeurs, 120 boulevard Saint-Germain, Paris 6e, France, 1956.

The first edition of this work appeared in 1943, authored by Professor René Ledoux-Lebard and Dr. Garcia Caldéron. At that time, it constituted the largest and most complete textbook on roentgen technique published in any language. Following the death of the first author, his son, Guy Ledoux-Lebard, who has also achieved distinction, has collaborated with Dr. Caldéron in the production of this second edition, published late in 1956.

The immense progress made in medical radiologic technique in the course of the intervening years rendered it necessary to completely reset the type of the book. We now have before us a magnificant volume of 1,148 pages, with 746 figures, illustrating modern new procedures as well as the time tested techniques which have been in use since the early days. Scores of ingenious new positions are described for the study of various portions of the skeleton. Nearly 500 pages are devoted to a discussion of the diagnostic roentgen techniques used for examination of the skeleton. Special chapters are devoted then to the nervous system, circulation, respiratory apparatus, digestive tube, urinary and genital apparatus, and foreign bodies.

There is an excellent index and an enlarged bibliography, containing many valuable source references which will prove helpful to those interested in the evolution of radiology.

There are no actual reproductions of roentgenograms, but the line drawings leave nothing to be desired; they are very satisfactory and very instructive.

Laminagraphy, the direct enlargement of roentgenograms, radiophotography, and radiocinemaphotography, as well as electrokymography, have found their place and are adequately described. A new chapter has been added on intestinal obstruction. The new, special procedures involving the use of contrast materials have also been given very special and detailed attention.

This book is adapted not only to the beginner in medical radiology, but the experienced physician specializing in this branch of medicine will also find it very helpful.

James T. Case, M.D.

Borderlands of the Normal and Early Pathologic in Skeletal Roentgenology. By Professor Dr. Alban Köhler. Completely revised by Dozent Dr. E. A. Zimmer, Bern/Fribourg. English translation arranged and edited by James T. Case, M.D., D.M.R.E. (Cambridge), Professor Emeritus of Radiology, Northwestern University Medical School, Chicago; Director, Memorial Cancer Foundation, Santa Barbara, California. Tenth edition. Cloth. Price, $24.50. Pp. 723, with 1,282 illustrations. Grune & Stratton, Inc., 381 Fourth Avenue, New York 16, New York, 1956.

For many years, Professor Alban Köhler's book has been regarded as one of the classics of roentgenologic literature. First published in 1910, it rapidly became a standard reference text among radiologists throughout the world, appearing in no less than eight editions during the ensuing thirty-three years. For approximately eight years following World War II it appeared that one of the truly great books in roentgen diagnosis was no longer to be available, but Dr. E. A. Zimmer altered this unfortunate situation by means of a thorough revision, which appeared as the tenth edition in 1953. The English translation of this edition by Dr. J. T. Case made its appearance in 1956.

Zimmer has done a creditable job in his revision. Not only has Köhler's original thesis been maintained, it has been substantially enhanced by deleting certain material which is now regarded as distinctly pathologic, and at the same time adding numerous skeletal variants which clearly belong in the "borderlands" category.

The text of the book is voluminous and, although at times it gives one the impression of being largely a detailed bibliography, it is reasonably appropriate for a reference book of this sort. Incidentally, there are literally thousands of references in the bibliography, which must be one of the most comprehensive reference lists available anywhere in a single volume.

Although roentgenographic reproductions printed in the positive form ordinarily are anathema to this reviewer, it must be stated that, in this instance, they are uniformly excellent and, without doubt, constitute the volume's outstanding feature.

Roentgenologists, orthopedists and all other physicians dealing with skeletal roentgenology will find this book to be one of the most active volumes in their "working" libraries. We owe a profound debt of gratitude to Dr. Case for making the English translation available.

John F. Holt, M.D.

Vol. 78, No. 6

ABSTRACTS OF RADIOLOGICAL LITERATURE

Department Editor: T. Leucutia, M.D., Harper Hospital, Detroit 1, Michigan

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ROENTGEN DIAGNOSIS

Head

Richards, Albert G. Roentgen-ray radiation and the dental patient. *J. Am. Dent. A.*, April, 1957, *54*, 476–487. (From: School of Dentistry, University of Michigan, Ann Arbor, Mich.)

This paper deals with the effects of roentgen rays on the skin and genes of the patient, the amount of radiation required to produce these effects as compared with the amount of radiation administered to these tissues during oral roentgen examination, and the methods of reducing the amount of roentgen radiation used for oral diagnostic purposes.

A dental roengenographic apparatus run at 65 kv. and 7.5 inch target skin distance requires a dose of 165 r in air to produce erythema on a skin area $1\frac{1}{8}$ inches in diameter with a filter of 1 mm. of aluminum. The author recommends that no facial area be exposed to more than 110 r in any two week period. Recovery from skin effect of radiation sets in promptly and continues at a rapid rate with about half being lost in the first twelve hours. Slightly more than 80 per cent recovery is achieved by the end of the fourth day.

A 14-film dental roentgenographic examination at 65 kv. and 10 ma. with an 8 inch cone, and 0.5 mm. Al filter averaged 55 to 77 r to the skin of the face.

Intraoral roentgenograms utilizing 90–95 kv. can be made with reduced exposure of skin, without significant increase in scattered radiation. Reducing the volume of irradiated tissue by using smaller cone apertures will reduce this scatter as well as the extent of skin overlapped by the primary beams. Addition of 1.5 mm. of aluminum filtration reduces roentgen dosage without seriously affecting the contrast of the image. This requires 43 per cent increase in exposure time, but yields 57 per cent reduction in roentgen dose.

Increasing the target skin distance from 8 to 16 inches effects very little reduction in dosage, particularly with high kilovoltage. It is less than 1 per cent. Faster films allow up to 100 per cent reduction of exposure to the patient. Faster timers are indicated to permit the fractional exposures incident to these faster films.

The genetic effects of radiation on the genes are cumulative and irreversible regardless of whether the exposure is long or short, of high or low intensity. Ninety-nine per cent of these are harmful to the species. Geneticists generally agree that 30 to 80 r to the human gonads will double the spontaneous mutation rate. It is recommended that the average exposure to the population's reproductive cells be limited to 10 r from conception to age thirty. About one-third of this is currently received from medical and dental roentgenographic examinations. If 20 periapical examinations of 14 exposures each were made of individuals during the first 30 years of life, the male gonads would receive about 0.3 r and the female gonads 0.05 r.

The author furnishes tables for rapid conversion of the various factors which directly or indirectly control the amount of radiation exposure to the dental patient. These factors include target film distance, diameter of primary beam, filtration, kilovoltage, film speed, developing time, and milliampere seconds.—*John A. Campbell, M.D.*

Updegrave, William J. Roentgenographic observations of functioning temporomandibular joints. *J. Am. Dent. A.*, April, 1957, *54*, 488–505. (From: Temple University School of Dentistry, Philadelphia, Pa.)

The value of temporomandibular joint roentgenography varies in the opinion of different investigators, but the majority acknowledge the assistance good roentgenographic evidence contributes. With this view in mind, the author presents a simplified technique for roentgenography of the temporomandibular joint which, by using a few easily constructed accessories, could be performed without special training.

One of the methods of studying function of the temporomandibular joints is cinefluorography—a motion picture of fluorescent images of the joints. The equipment required for this type of examination is costly and its narrow applicability means that its use is limited to research centers, teaching institutions and hospitals.

In lieu of this the serial method of making multiple roentgenographic exposures is recommended. This technique makes it possible to record the various condylar positions on the same film by maintaining the head of the patient in a fixed position, utilizing the slide tunnel principle and moving the cassette for as many as six exposures on one film. The change in condylar-fossa relationship can be followed with each change in mandibular function. This technique has some advantages over cinefluorography in that the examination can be performed more readily, the films are examined more easily, tracings from the roentgenograms can be made and compared, minor changes in function are discerned more readily, measurement of components in their natural relationship is possible, and the parts are portrayed in their normal size.

Serial roentgenographic studies of condylar functions in Classes I, II, and III types of occlusal relationships were made.

Observations were recorded on the range of condylar translation and on the uniformity of condylar function of 90 dental students.

The pertinent facts essential to an understanding of the roentgenographic observations made in 6 patients are included.—*Frank L. Lesko, M.D.*

Riemenschneider, Paul A. Trigonocephaly. *Radiology*, June, 1957, *68*, 863–865. (Address: 736 Irving Avenue, Syracuse 10, N. Y.)

Trigonocephaly is a congenital deformity of the skull characterized by a keel-like ridge at the site of the metopic suture. Certain authors have classified this condition with the various types of premature closure of the cranial sutures, the deformity being ascribed to intrauterine closure of the metopic suture. Reproductions of skull roentgenograms of two patients with this deformity are presented. Both show small frontal bones with a shallow frontal fossa and orbits set closely together, suggesting a hypoplasia of the ethmoid bone. The metopic suture was closed in one patient and open in the other patient. These changes discount the hypothesis that trigonocephaly is a result of intrauterine closure of the metopic suture and support the conclusion that the underlying cause is a hypoplasia of the frontal lobes.—*Harold C. Hamilton, M.D.*

Harris, Phillip, and Udvarhelyi, George B. Aneurysms arising at the internal carotid-posterior communicating artery junction. *J. Neurosurg.*, March, 1957, *14*, 180–191. (From: Department of Surgical Neurology, Royal Infirmary, Edinburgh, Scotland.)

A common place for intracranial aneurysms is at the junction of the internal carotid and posterior communicating arteries. Twenty-seven per cent of intracranial aneurysms in this series of 326 were at this location; 10 patients had multiple aneurysms.

Clinical findings include subarachnoid hemorrhage, oculomotor nerve palsy, contralateral hemiparesis and ipsilateral frontal and orbital pain.

Subarachnoid hemorrhage occurred in 75 patients and in 23 of these it occurred at the end of the third week. Ipsilateral oculomotor palsy was seen in 40 patients. Trochlear nerve palsy was seen in only 5 cases.

Angiography is necessary for diagnosis but prolonged unconsciousness, severe confusion and abnormalities of blood pressure will delay this procedure. Twenty-six patients had angiography within seven days after the onset of symptoms and 12 more within fourteen days.

At surgery almost all the aneurysms were directed backward, downward and lateralzely and the si varied from 1.5×7.5 mm. to 29×15 mm. Anastomotic circulation between the two internal carotids is important in relation to therapy and is routinely tested. Sixty-six patients had a proximal ligation of carotid arteries in the neck and 12 had an operation for direct obliteration of the aneurysms. The former operation is preferred if anastomotic circulation on the two sides is good. The common carotid is ligated first and the internal carotid after a period of three months.

Complications of ligating the carotid included a contralateral hemiparesis in 17 patients, arterial hypotension with neurologic deterioration in several and psychologic changes in a few. Death occurred in 4 patients from brain stem ischemia. Recurrent bleeding, hemiparesis, oculomotor nerve palsy and epilepsy occurred in a few cases after direct obliteration of the aneurysm.

Proximal ligation of the artery is suitable when there is good anastomotic circulation and if the aneurysm is large or sessile. The direct procedure is required when the anastomotic circulation is poor, when there is a contralateral or ipsilateral second aneurysm or if the aneurysm fills on testing the contralateral anastomotic circulation.—*George Werner, M.D.*

Neck and Chest

Schlungbaum, W. Zur sogenannten Lungenadenomatose. (Contribution to so-called pulmonary adenomatosis.) *Fortschr. a. d. Geb. d. Röntgenstrahlen u. d. Nuklearmedizin*, June, 1957, *86*, 679–690. (Address: Spandauer Damm 130, Berlin-Charlottenburg 9, Germany.)

After mentioning the multiple synonyms, the unknown etiology, and the basic differences between the bronchial carcinoma and the pulmonary adenomatosis, also called bronchiolar or alveolar cell carcinoma, the author presents 8 cases, 5 of which were proved on autopsy or by biopsy to be pulmonary adenomatosis.

The first case had cough, right chest pain, and muco-serous sputum. The roentgenogram showed diffuse miliary to lenticular densities in the right lung and a homogeneous shadow on the left due to effusion. The initial diagnosis was tuberculosis until tumor cells were found in bronchial smears. The death occurred after seven months of illness and on autopsy, typical diffuse infiltration of the alveoli by a low cubical to columnar epithelium was found with few signet-ring cells. The only metastases were noted in the bifurcation lymph nodes.

The second case of a seventy-eight year old male had swallowing difficulties as a presenting symptom. The roentgen examination revealed a stenotic lesion in the upper third of the esophagus with large hilar and upper mediastinal shadows and confluent densities in the lower lobes of both lungs. The autopsy demonstrated typical alveolar cell carcinoma in both lower lobes, middle lobe, and left upper lobe, metastases in the bifurcation and retro-esophageal lymph nodes with penetration and perforation into the upper third of the esophagus simulating primary carcinoma of the esophagus. The total duration of illness was one and one-half years.

The third case of a forty-four year old woman had a persistent cough as the main complaint. On the basis of roentgenograms which showed patchy densities in both lungs, an initial diagnosis of miliary

tuberculosis was made. Tumor-suspect cells were found in the sputum. Two roentgenograms made three weeks apart showed marked extension of the process in both lungs. This was later shown to be due to superimposed unspecific pneumonia. Otherwise, the autopsy showed the lesions to be typical of pulmonary adenomatosis.

The fourth case of a fifty-three year old male showed a plum-sized round shadow in the apical segment of the right lower lobe with cough as the presenting symptom. In sputum, cells suspect of alveolar cell carcinoma were found. The radiation therapy induced marked regression of the shadow and improvement of general condition. The patient died two years later with symptoms of passive congestion. The autopsy showed a fist-sized, centrally necrotic tumor penetrating into the main bronchus of the right lower lobe with structure of alveolar carcinoma histologically. Metastatic lesions were found in the hilar paratracheal lymph nodes and around the vena cava. There was bilateral pleural effusion, perigastric metastatic lesions, and metastases in the adrenal glands.

The fifth case of a fifty year old male had blood-tinged sputum and uncharacteristic complaints. The roentgenograms showed ill-defined infiltration in the right lower lobe with decrease of volume. The bronchograms revealed bronchiectasis in the right lower lobe. Lobectomy of the right lower lobe disclosed loculated, ectatic changes in the right lower lobe bronchus with neoplastic areas, histologically proved as pulmonary adenomatosis originating in the bronchiectatic segments. In this case, congenital bronchiectatic changes were combined with secondary pulmonary adenomatosis.

The sixth case of a fifty year old woman showed also congenital malformations of the bronchi. The biopsy of the left lung was not completely conclusive of pulmonary adenomatosis although some of the areas appeared suspect.

The seventh and eighth cases are included because of differential diagnostic considerations, each representing a bronchial carcinoma with lymphatic spread causing multiple, small, blotchy, round densities similar to those found in pulmonary adenomatosis.

Only 2 of the author's 5 cases showed roentgenologic findings suggesting primarily the possibility of pulmonary adenomatosis. The second case with the stenotic lesion in the esophagus, the fourth case with the round shadow in the apex of the right lower lobe, and the fifth case with ill-defined infiltration in the right lower lobe—pathologically around the congenital bronchiectatic changes—were of interest showing the uncommon varieties of pulmonary adenomatosis.—*Nathan Kriss, M.D.*

Voluter, G., and Zürcher, W. Contribution à l'étude radio-morphologique et anatomo-clinique de l'adénomatose pulmonaire. (Contribution to the morphologic radiology and clinical anatomy of pulmonary adenomatosis.) *Radiol. clin.*, March, 1957, *26*, 59–74. (Address: G. Voluter, Institut de Radiologie médicale de l'Université; and W. Zürcher, Institut d'Anatomie pathologique de l'Université, Geneva, Switzerland.)

This is the case report of a female aged seventy with dyspnea, retrosternal pain, loss of weight, cough without sputum and a temperature of about 100.5° F. There were acid fast bacilli in the gastric juice. The roentgenologic examination of the chest revealed numerous rather large foci similar to silicosis, and which were interpreted as due to miliary tuberculosis. The pathologic report, however, was alveolar carcinoma (pulmonary adenomatosis), there being no evidence of tuberculosis. There were no metastases.

The authors note that the disease may appear roentgenographically as a solitary nodular focus of medium size, as nodular agglomerations or as a diffuse shadow. The solitary nodular focus may be modified in appearance by calcifications and by contiguous shadows due to pleural reaction, atelectasis, emphysema, old fibrosis and intercurrent disease. There is no pathognomonic finding in adenomatosis and differentiation from any other miliary process is not possible.—*Marcy L. Sussman, M.D.*

Haidak, Gerald L., Caplan, Bernerd, and Maloney, Walter H. Air contrast bronchography. *J. Thoracic Surg.*, July, 1957, *34*, 63–66. (Address: G. L. Haidak, 769 North St., Pittsfield, Mass.)

The authors describe a modified technique of bronchography which is thought to result in better bronchograms more consistently than with the usual procedure.

After passing an intratracheal catheter and anesthetizing the bronchial tree, well heated (five minutes in a sterilizer) dionosyl is injected into the desired lobe. After the contrast material has entered all of the segmental bronchi of the lung or part of the lung in question, 150–200 cc. of air is quickly injected into the bronchial tree via the tracheal catheter. The latter procedure produces a contrast type of mucosogram not unlike that seen in air contrast colon studies.

Non-Bucky posteranterior and oblique exposures at 72 inch tube-film distance were used. The lateral studies were made with a Bucky grid at a 42 inch tube-film distance. The 3 bronchograms reproduced are of good quality. No untoward side effects have been noted from the air injection.—*P. C. Olfelt, M.D.*

Greenspan, R. H., and Feinberg, S. B. Salmonella bacteremia: A case with miliary lung lesions and spondylitis. *Radiology*, June,

1957, *68*, 860–862. (Address: S. B. Feinberg, 737 E. 22nd St., Minneapolis 4, Minn.)

The authors present a case in which miliary lung lesions and spondylitis of two lumbar vertebrae were found. This case was thought to be of interest because, although pulmonary and bony manifestations of salmonellosis have been reported with some frequency, no example of miliary lung lesions due to this cause could be found in the literature.

The initial admission chest roentgenogram showed a coarse miliary pattern bilaterally with the lesions varying in size from 1 to 3 mm. in diameter. Follow-up chest roentgenograms obtained several months later showed regression of the chest lesions with only a faint residual granular pattern evident. While initial spine roentgenograms were negative, those obtained about one month later showed destructive lesions in 2 adjacent lumbar vertebrae with a collapse of the disk space of the type common to an inflammatory process. These spine lesions showed evidence of healing on subsequent examination.

Blood cultures initially positive for Salmonella Tennessee became negative following antibiotic therapy. Stool cutures, however, remained positive until the gallbladder, which contained calculi, was removed some six months after the first admission.—*Donald N. Dysart, M.D.*

SCHAEDE, A., and THURN, P. Zur Frage des systolischen Restblutes beim Menschen; Angiokardiographische Beobachtungen. (The systolic residual blood in man; angiocardiographic observations.) *Fortschr. a. d. Geb. d. Röntgenstrahlen u. d. Nuklearmedizin*, June, 1957, *86*, 696–710. (From: Medizinische Universitätsklinik, Bonn, Germany.)

The amount of blood remaining in the ventricles after systole has been the subject of many investigations since it provides information about the heart capacity. The roentgenographic volume determination before and after Valsalva maneuver as previously used by some investigators does not give a true picture because the Valsalva maneuver interferes with venous return. The serial cardiography (cineroentgenography) furnishes more accurate results providing the examination is performed in horizontal position and at least sixteen frames per second are taken for demonstration of the maximal systole and diastole.

The authors consider the problem of residual systolic blood in three different situations: 1) the ventricle under normal stress; 2) the ventricle under volume stress; and 3) the ventricle under pressure stress.

With reference to number 1, three levograms in straight posteroanterior view are presented in maximal systole and diastole of ventricles with small amount of residual blood retained centrally at the atrioventricular ostium during maximal systole.

With reference to number 2, an eight year old and an eleven year old patient with open duct are presented, both in levograms, the first following retrograde aortography, the second after venous angiocardiography. Planimetric measurements of opacified surfaces of the left ventricle during systole and diastole reveal a 2:1 ratio of stroke volume to residual blood. The atrioventicular plane (mitral valve) shows more extensive movements than in normal heart.

With reference to number 3, as an example of pure pressure stress on the ventricles, a compensated pulmonary stenosis is selected for the right heart and compensated aortic stenosis for the left. Dextrograms and levograms of a three year old and dextrograms of a ten year old patient with pulmonary stenosis, as well as a levogram of a four year old with aortic stenosis are presented as examples. It is shown that the residual systolic blood is smaller in the aortic stenosis in the left ventricle than the corresponding amount in pulmonary stenosis in the right ventricle. This difference is due to the physiologically stronger myocardium on the left.

In addition to these cases, all of which were compensated, a case of mitral insufficiency with right heart failure is presented, a thirteen year old patient showing in dextrogram large residual systolic blood volume in all portions of the right ventricle in contrast to the previous slight residual blood volume accumulated only at the atrioventricular level in compensated cases.

The authors do not rely on these studies to decide whether the increase in residual blood is a compensatory mechanism or a sign of insufficiency. They think that this question could be decided only on the basis of clinical symptomatology and direct intracardiac pressure measurements. These findings are in accordance with the law of cardiac dynamics (Frank-Straub-Starling) which states that a fully efficient heart has a smaller residual blood than stroke volume but not the failing heart.—*Nathan Kriss, M.D.*

RIVKIN, LAURENCE M., READ, RAYMOND C., LILLEHEI, C. WALTON, and VARCO, RICHARD L. Massive atelectasis of the left lung in children with congenital heart disease. *J. Thoracic Surg.*, July, 1957, *34*, 116–125. (From: The Department of Surgery, University of Minnesota Medical School, Minneapolis, Minn.)

This group of cardiac surgeons has encountered atelectasis of the left lung, preoperatively in some cases and postoperatively in others, as a frequent complication in certain types of congenital heart disease. Eight representative cases of this syndrome are described in detail. Five of these patients had ventricular septal defects, 1 an aorticopulmonary window, 1 a patent ductus arteriosus with coarctation of the aorta, and 1 total anomalous pulmonary venous return to the right atrium. In 5 cases, the atelectasis was present prior to surgical correction of

the defect, and in 3, the atelectasis appeared in the postoperative period. All of these atelectatic patients had an increased blood flow through the lungs and serious pulmonary hypertension. At surgery the pulmonary artery was observed to be large, tense and pulsatile in all cases.

The mechanism for the production of this precise form of atelectasis is thought to be compression of the left main bronchus by an enlarged left pulmonary artery. This observation is based on findings at surgery and at postmortem examinations. Bronchoscopy revealed extrinsic type of obstruction of the left main bronchus at the site where the left pulmonary artery crosses it. A similar type of compression by an enlarged left atrium has not been noted. A similar massive atelectasis of the right lung has not been observed in these infants with pulmonary hypertension presumably because of a difference in the spatial relationships of the right main bronchus and the right pulmonary artery. This condition seems to be confined to infants probably because of the small lumen and soft nature of their bronchus.

The authors believe that the onset of roentgenologically demonstrable obstructive emphysema represents an urgent indication for curative cardiac surgery before massive collapse occurs. The appearance of partial or total collapse of the left lung is also felt to be an indication for surgery since the spontaneous resolution of this type of atelectasis has only been observed to follow a curative operation. The response to the surgery is not immediate since the vascular changes primarily responsible regress slowly.—*Paul C. Olfelt, M.D.*

Oliva, Luigi, and Besio, Gian Luigi. Studio sperimentale e sistematizzazione delle ombre di trasporto endotoraciche in stratigrafia assiale trasversa. (Experimental study and evaluation of the so-called "transport shadows" in transverso-axial laminagraphy of the chest.) *Radiol. med.*, June, 1957, *43*, 551–567. (From: Istituto di Radiologia della Università, Genova, Italy.)

This paper is based on the vast experience acquired by Vallebona and his associates on horizontal laminagraphy and deals with the interpretation of particular images that they call "transport shadows," and which are normally seen in horizontal laminagrams of the chest.

These shadows can be grouped under four headings: (1) Intrathoracic sickel-shaped shadows. These are faintly radiopaque shadows and are seen generally in the lowermost sections of the chest in correspondence with the anterior costomediastinal sinuses. (2) False flattenings of the cardiac silhouette. These shadows are seen in the laminagrams of the heart, and are generally situated along its right posterior lateral border, giving a flat appearance to the heart. (3) Intrathoracic pseudo-rib shadows. These are observed in higher sections of the chest as bilateral shadows departing from the images of the vertebrae and directed laterally with slight concavity. (4) Parietal polygonal shadows. These are localized along the lateral wall of the chest in correspondence with the ribs.

The research done previously by Vallebona *et al.* (*Radiologia*, 1953, *9*, 727–738, and *Acta Anat.*, 1954, *22*, 336–339) and by the present authors has shown that the "transport shadows" are simply satellite shadows. The ribs, because of their position, the heart, vertebral column, etc. because of their opacity, leave on the horizontal laminagrams these secondary shadows.

In order to interpret correctly the transverse axial laminagram of the chest, therefore, it is important to recognize these shadows which not infrequently can give rise to some doubts in the roentgen diagnosis of intrathoracic pathology.—*A. Govoni, M.D.*

Abdomen

Ochsner, Seymour, and Penick, Rawley M., Jr. Hemangioma of the small intestine. *Radiology*, June, 1957, *68*, 845–848. (Address: S. Ochsner, Ochsner Clinic, 3503 Prytania St., New Orleans, La.)

A case of capillary hemangioma of the small intestine in a sixteen-year-old girl is presented. The patient had intermittent episodes of cramping abdominal pain, and a chronic severe anemia was present. Roentgenologic studies of the small intestine disclosed several soft polypoid filling defects in a segment of the mid-jejunum with the delayed roentgenogram showing a cluster of peculiar, rounded, barium-coated lesions in the left side of the abdomen. A 17 cm. segment of jejunum was resected and pathologic examination showed seven polypoid lesions arising in the mucosa, which were diagnosed histologically as multiple capillary hemangiomas. The patient has remained well more than six and a half years postoperatively.

Hemangiomas of the small intestine are rare lesions which severely test the diagnostic capabilities of the radiologist. Of 1,399 cases of tumors of the small intestine recorded in the literature, only 79 had been correctly diagnosed before operation, in each instance on the basis of roentgenologic evidence. In this collected series, there were 127 vascular tumors and in only 3 of these had a preoperative roentgenologic diagnosis of benign tumor been made. The prime indications for roentgenologic examination of the small intestine are persistent chronic or recurrent periumbilical pain, diarrhea in the absence of disease of the colon, and obscure intestinal bleeding.—*Harold C. Hamilton, M.D.*

Berg, R. M., and Berg, H. M. Coproliths. *Radiology*, June, 1957, *68*, 839–844. (Address:

R. M. Berg, Quain and Ramstad Clinic, Bismarck, N. D.)

The purpose of this paper is to remind the radiologist to be "coprolith-conscious." Coproliths were not diagnosed in the authors' department before 1949 but in the first five years after becoming "coprolith-conscious" 42 cases were seen. The word coprolith is used to emphasize the radiopacity of the concretion and thus distinguish fecaliths which are visible roentgenographically from others frequently found in the appendix.

The incidence of coproliths varies considerably according to the material from which the cases are selected, but a compilation of all the figures found in the literature gives an average incidence of about 5 per cent. The majority of patients in the present series were under twenty-one years of age with 11 of the patients under five years of age.

A calcified shadow or shadows in the right lower quadrant should suggest the possibility of the presence of a coprolith. The shape is usually oval but may be round, cylindrical, triangular, or irregular. Most coproliths are 5 to 20 mm. in diameter, but they range in size from just barely visible to 30 to 40 mm. in diameter. They are usually found in the right lower quadrant, but may occur in the right upper quadrant, the left lower quadrant, or the minor pelvis. They must be differentiated from bone islands, ureteral and vesical calculi, calcified mesenteric lymph nodes, phleboliths and vascular plaques, foreign bodies, radiopaque medication, calcified appendices epiploicae and ovarian and uterine calcification.

A review of the histories in this series reveals that 50 per cent of the cases would not have had sufficient evidence, without the roentgenologic findings, for exploration, despite the history and physical and laboratory examinations. In the presence of a coprolith in a patient with acute abdominal symptoms there is at least a 90 per cent chance that the patient has an acute appendicitis. In 49 per cent of the cases in this series, the appendix was gangrenous or perforated. Most authors recommend an immediate appendectomy whenever a coprolith is found. The findings in this series are in agreement as far as the younger patients are concerned, but operation would not appear to be necessary in the symptom-free patients.—*Harold C. Hamilton, M.D.*

SALEMBIER, Y., BONTE, G., and LÈQUES, B. Confrontation des résultats obtenus par cholangiographie orale ou intra-veineuse et cholangiographie peropératoire dans les affections du sphincter d'Oddi. (Comparison of the results obtained by oral or intravenous cholangiography with those of operative cholangiography in diseases of the sphincter of Oddi.) *J. de radiol., d'électrol. et de méd. nucléaire*, March–April, 1957, *38*, 207–212. (From: Service de Clinique chirurgicale and Service de Radiologie de l'Hôpital de la Charité, Lille, France.)

The comparison about which the authors write is admittedly very difficult, primarily because cases of noncalculous disease with proved dystonia of the sphincter of Oddi are few. The roentgenologic examination is seldom sufficiently extensive and does not include pharmacodynamic tests that would establish the diagnosis. Because of current practice, radiomanometric observations and cholangiography at operation usually precede the oral or intravenous examination which may not be made for a year or more.

The authors have made the latter studies after the performance of a cholecystostomy "a minima." Four pharmacodynamic tests are made: without preparation, after morphine, after atropine and after xylocaine-oil. They feel that these observations, although perhaps premature, establish a fairly definite picture of stenosis of the sphincter of Oddi, and less definite findings in hypertony of the sphincter. It may be possible to make the latter diagnosis from the oral or intravenous cholangiogram.—*Marcy L. Sussman, M.D.*

MOSELEY, JOHN E. Radiographic demonstration of choledochal cyst by oral cholecystography. *Radiology*, June, 1957, *68*, 849–851. (Address: Department of Radiology, The Mount Sinai Hospital, New York, N. Y.)

Choledochal cyst or idiopathic dilatation of the common bile duct is a congenital localized dilatation, the exact etiology of which is obscure. It occurs most commonly in children and young adults with the incidence four times as great in females as in males. The diagnosis may be strongly suggested by the clinical triad of abdominal pain, tumor, and jaundice, and the clinical course is characterized by intermittency of the symptoms.

Nearly 200 cases of choledochal cyst have been reported. This case, reported by the author, is the only one in which the cyst and gallbladder were visualized by oral cholecystography, and the author feels that the use of telepaque made this possible. The importance of the preoperative diagnosis of this condition is stressed as the mortality from surgery is much reduced when the surgeon is prepared for this eventuality.—*Donald N. Dysart, M.D.*

GENITOURINARY SYSTEM

MOLINA, LUIS F. RODRÍGUEZ, and SABUCEDO, RAFAEL MOLINA. Ureter retro-caval. (Retrocaval ureter.) *Radiología*, Panamá, June, 1957, *7*, 115–119. (Address: L. F. Rodríguez Molina, Calle 2 N. 607, Vedado, Habana, Cuba.)

Retrocaval ureter is an anomaly in which the right ureter deviates toward the midline behind the inferior vena cava in the lumbar region.

Symptoms are due to urinary obstruction and stone formation. Diagnosis is made by pyelography. Treatment depends on the severity of obstruction, infection and stone formation.

A case is reported in which the proximal dilated ureter was resected and the distal portion of the ureter was sutured to the renal pelvis.—*Charles M. Nice, Jr., M.D., Ph.D.*

Soteropoulos, C., Kawashima, E., and Gilmore, John H. Cystitis and ureteritis emphysematosa. *Radiology*, June, 1957, *68*, 866–868. (Address: 836 Wellington Ave., Chicago 14, Ill.)

A case of cystitis emphysematosa complicated by ureteritis emphysematosa is reported. Several articles have appeared recently regarding cystitis emphysematosa but this is believed to be the first report of the complication of ureteritis emphysematosa. Roentgenograms showed the characteristic findings of cystitis emphysematosa with extension of the emphysematous changes into the ureters. Forty-eight hours later the gaseous vesicles had disappeared, though mucosal inflammation, as shown cystoscopically, persisted for several weeks. The transient nature of the emphysematous changes may account in part for the fact that ureteritis emphysematosa has not been reported more frequently. The functional capacity of the uretero-vesical junction to prevent regurgitation into the ureters may also exert a similar effect on extension of gaseous vesicles from the mucosa and submucosa of the urinary bladder into the ureters. It is believed that emphysematous changes in association with cystitis may occur more frequently than is appreciated because of the transient nature of these changes.—*Harold C. Hamilton, M.D.*

Nervous System

Todd, Edwin M., and Gardner, W. James. Pantopaque intravasation (embolization) during myelography. *J. Neurosurg.*, March, 1957, *14*, 230–234. (From: Department of Neurological Surgery, The Cleveland Clinic Foundation, and The Frank E. Bunts Educational Institute, Cleveland, Ohio.)

Hinkel first described intravasation during myelography in 1945, when at fluoroscopy he observed a rapidly shrinking subarachnoid oil column and radial finger-like projections with subsequent formation of the oil column to the right of the lumbar spine. There have been only 5 other reported cases. In one case attempts to remove the medium were discontinued because of bleeding at the puncture site and the patient subsequently developed intrathoracic distress at which time a roentgenogram of the chest was made and interpreted as pantopaque emboli to the lung.

The case report included in this paper was similar to the one mentioned above; however, serial spot films and a lateral roentgenogram demonstrated that forward displacement of the spinal needle into the anterior internal venous plexus was the cause of intravasation. Chest roentgenograms were made immediately, but failed to reveal evidence of embolization. Roentgenograms of the skull the following day showed faint linear streakings suggesting intracranial venous distribution of the medium.

The venous pathways of intravasated pantopaque have been demonstrated by previous authors to be the intervertebral veins which carry the contrast material to the lateral sacral and lumbar veins and hence to the inferior vena cava.

It is concluded that occurrence of intravasation is probably more frequent than the reported cases would indicate and should, therefore, be suspected when there is discrepancy between the amount of medium injected and withdrawn or when intrathoracic distress attends or follows myelography, especially after a hemorrhagic tap.—*Paul Inlow, M.D.*

Skeletal System

Larsen, Lawrence L., and Wright, Hobart H. Para-articular ossification, a complication of anterior poliomyelitis; a case report. *Radiology*, July, 1957, *69*, 103–105. (Address: L. L. Larsen, 2900 W. Oklahoma Ave., Milwaukee 15, Wis.)

The authors present the case report of a twelve year old white girl with laboratory confirmed anterior poliomyelitis involving all the extremities, but most pronounced in the right arm and left leg. Roentgen studies of the left hip showed extensive para-articular ossification, this finding being absent from all other joints on survey roentgenograms. Laboratory studies in the reported case showed no inherent defects in bone metabolism. This unusual complication does not seem to have been reported previously in the roentgen literature except by Caffey.

Follow-up studies over the next six months showed changes in this hip consistent with maturing bone. Surgery performed ten months after the onset of the disease showed mature bone arising from the anteromedial aspect of the upper femur and extending to the joint capsule and ilium. Gross and microscopic examination resulted in the diagnosis of reactive bone formation. Free range of motion of the hip was obtained by partial surgical excision of the bony mass.

No new theory was advanced as to the mechanism of ossification. The concepts of tissue atrophy, degeneration and metaplasia remain unproved and the etiology remains obscure. Roentgen therapy may be beneficial for minimal ossification discovered early in convalescence.—*Z. Petrany, M.D.*

Caffey, John. Infantile cortical hyperostosis; a review of the clinical and radiographic features. *Proc. Roy. Soc. Med.*, May, 1957, *50*, 347–354. (From: Departments of Pediatrics and Radiology, College of Physicians and Surgeons, Columbia University, and the Babies Hospital, New York, N.Y.)

Although this condition was first named and recognized as an entity in 1945, a few isolated instances of similar cases were reported, but unclassified, in the fifteen years prior to that date. It is presumed that this is a new entity rather than one which has been overlooked in the past. It is now of sufficiently frequent incidence that the clinical roentgenographic features have been described in more than 100 cases. One of the most striking clinical features is the early age of onset. There are no valid cases in which the age at onset has been greater than five months, and in several instances similar pictures have been reported prenatally, the earliest in a dead fetus at the age of twenty-four weeks. This early age of manifestation points to the importance of transmission from the mother as a factor in pathogenesis of all cases.

The most common first symptom is sudden swelling of the jaw and face, and in all of the author's cases, the mandible has been involved. All other bones of the skeleton are subject to involvement and new swellings may occur in one site while they are subsiding in other places. The swellings occur over the involved bones and are accompanied by regional limitation of movement and tenderness but never discoloration or edema of the overlying skin. The swellings are wooden hard and fixed to the underlying bones. Fever is variable but may be high and prolonged. The only laboratory finding of positive value is an increase in sedimentation rate which varies directly with the activity of the lesion.

The clinical course is highly variable. In the mildest cases facial swelling disappears in a few weeks. In other cases symptoms may regress and suddenly recur in new or other areas. In some cases swellings have persisted up to twenty months without regression and recurrence has occurred as long as seven years after complete subsidence of the original attack. At least three patients have died.

The roentgenographic findings are identical whereever they are found. The cortical walls of bones which underlie the swelling thicken externally. The hyperostoses finally heal by reaming out of the hyperostoses, producing a thin walled bone with dilated medullary cavities. Eventually the bone resumes normal appearance although patchy sclerosis of the mandible may persist for some time after the process subsides.

All bacterial, viral, and immunologic studies in the blood, and biopsy specimens have given negative results. Urine and cerebral spinal fluids have been normal. Chemical and vitamin tests of the blood have proved negative.

Morbid anatomy has been studied incompletely because necropsies have not been reported in the classical form of the disease, and there is a dearth of biopsies in the earliest phase of the swelling. The hyperostoses are made up of normal but immature bone. In many cases there has been no microscopic evidence of inflammation although in other cases the presence of cellular infiltrates has suggested inflammatory reaction. There is no anatomic evidence that subperiosteal hemorrhage is a factor. The thickening of the periosteum may be mucinous in character and this feature has led to the erroneous diagnosis of sarcoma in several cases.

Since it has become evident that the disease is occasionally fatal and not infrequently recurrent and chronic, it is advisable to treat all patients. The adrenocorticosteroids are highly effective in all phases of the disease, and cortisone should be given in doses of about 200 mg. daily for a period of two to three weeks, at which time dosage should be reduced gradually to prevent rebound phenomena.—*Lois Cowan Collins, M.D.*

Perret, George. Diagnosis and treatment of diastematomyelia. *Surg., Gynec. & Obst.*, July, 1957, *105*, 69–83. (From: The Division of Neurosurgery, State University of Iowa College of Medicine, Iowa City, Iowa.)

The authors report 5 verified cases of diastematomyelia. All presented various types of adjacent skin defects such as hypertrichosis, dermal sinus or defective skin. One was associated with a thoracic myelomeningocele and another with a lipoma. All had neurologic disturbances of varying degree, commonly resulting in impaired function of one or both lower extremities. The affected extremity tended to be slightly smaller than normal.

Roentgenographic examination in these cases revealed spina bifida with fusiform widening of the spinal canal. There was evidence of a midline bony spicule in the spinal canal in 2 cases but the cord dividing septum may be cartilagenous or fibrous in nature and not cast any shadow. Myelography regularly outlined a midline septum which split the subarachnoid space into two columns, usually over several segments.

Appropriate operative intervention in 4 of these cases resulted either in clinical improvement or absence of progression of their neurologic disorders.—*Arthur E. Childe, M.D.*

Singleton, Edward B. The radiographic features of severe idiopathic hypercalcemia of infancy. *Radiology*, May, 1957, *68*, 721–726. (Address: Texas Children's Hospital, 6621 Fannin St., Houston 25, Texas.)

Idiopathic hypercalcemia in infants usually has an abrupt onset in early infancy after several months

of normal development. It is manifested clinically by loss of weight, anorexia, constipation, vomiting and hypotonia. Laboratory studies disclose hypercalcemia, elevation of the blood urea, and occasionally evidence of renal acidosis. Two types are recognized: a benign self-limiting type in which there are no distinctive roentgen findings and a severe type characterized by signs of mental retardation, hypertension, failure of normal development, and bone sclerosis with the long bones showing increased density of both the cortex and the trabecular structure. Craniostenosis has been reported in 2 cases and probably in a third.

A case of the severe form of idiopathic hypercalcemia of infancy in a seventeen-month-old infant is reported with special emphasis on the roentgenologic features.—*Harold C. Hamilton, M.D.*

Smith, George W., and Nichols, Pomeroy, Jr. The technic of cervical discography. *Radiology*, May, 1957, *68*, 718–720. (Address: G. W. Smith, Medical College of Georgia, Augusta, Ga.)

The authors describe a technique of cervical diskography which they have used in 70 patients. Several advantages are claimed for their technique: it can be used as an out-patient procedure; rapid absorption of the contrast medium obviates the need for its removal; fluoroscopy is not required; the procedure can be done in fifteen to twenty minutes; there is little morbidity.

The contrast medium, 70 per cent diodrast, is injected slowly by means of a tuberculin syringe, through a 9 cm., 21 gauge spinal needle. Only 0.5 to 1.0 ml. of the contrast medium is required for each disk space. If the disk space being injected is diseased, the patient complains of severe shoulder, arm, hand, and finger pain, or paresthesias simulating his admission complaints. Resistance encountered in making the injection suggests that the disk may be normal. Regular cervical spine roentgenograms, including oblique views, are promptly obtained.—*Dean Nichols, M.D.*

Blood and Lymph System

Viglioglia, Pablo Alberto. Los hemangiomas sistemicos; fistulas arteriovenosas congenitas; (a propósito de 6 observaciones). (Systemic hemangiomatosis; congenital arteriovenous fistulas [with six observations].) *Prensa méd. argent.*, Nov. 16, 1956, *18*, 3401–3415. (Address: Esparza 92, Buenos Aires, Argentina.)

This paper, written by a dermatologist, and based on the review of at least 59 bibliographic sources, stresses the fact that arteriovenous fistula, even when it seems to be localized to the skin or to a limb is always a systemic disease. In the 6 cases, seen by the author in the past three years, the right upper limb was involved in 3 patients, the left upper limb in 1 patient, the left lower limb in 1 patient, and both upper limbs and the right lower limb in 1 patient. Systemic hemangiomatosis is believed to be caused by a developmental abnormality having a mesodermal point of attack with ulterior (often multiple) localizations in the skin, the buccal mucosa, brain, orbit, gastrointestinal tract, liver, bones, etc. There is an abnormal peripheral "shunt" between the arterial and the venous system, functioning as an arteriovenous fistula, most often located in the lower extremities, but also described in the neck (carotidojugular), lung, intracranial, etc.

Cutaneous angiomata are present only in about 60 per cent of the cases with diagnosable shunt, so that integrity of the skin does not rule out the existence of arteriovenous fistula. When a limb is affected, it hypertrophies, and becomes from 5 to 50 per cent larger than the corresponding opposite limb. Roentgenographic study shows periosteal proliferation, exostoses, and sometimes osseous rarefactions. Arteriography reveals early venous phase, while phlebography demonstrates an irregular, atypical venous network with saccular dilatations. Vascular signs include a local "brouille," and enlargement of the left ventricle, eventually with decompensation.

The differential diagnosis includes acquired (posttraumatic) arteriovenous fistula, tropho- or lymphedema, cavernous lymphangioma, hemangioendothelioma (and -sarcoma), Kaposi's sarcoma, Recklinghausen's neurofibromatosis, and congenital hypertrophy (localized gigantism).

If diagnosis can be made in the first few months of life, radiation (radium or roentgen) therapy may be curative. Later, one will have to consider the cardiovascular status before deciding the extent of surgical intervention best tolerated or required; in most cases, vascular ligatures, with or without excision of the fistulous communication, will suffice, but sometimes even amputation is necessary.

The clinician will have to think of the possibility of systemic hemangiomatosis with arteriovenous fistula whenever there is even a localized vascular disturbance, such as atypical varices, varicose ulcers, or left cardiac (juvenile) insufficiency of obscure etiology. The radiologist must include this entity among his differential diagnosis of unilateral limb hypertrophy with periosteal reaction.—*E. R. N. Grigg, M.D.*

Goldin, Ralph R., and Silver, Maurice L. Ophthalmic artery aneurysm. *Radiology*, May, 1957, *68*, 727–730. (Address: R. R. Goldin, Albert Einstein College of Medicine, Yeshiva University, New York 61, N.Y.)

A case report of an ophthalmic artery aneurysm eroding the outer wall of the optic foramen is pre-

sented. Roentgenograms to show the optic foramina revealed erosion on the left and carotid angiography disclosed a large aneurysm of the left ophthalmic artery. The diagnosis was substantiated at operation.

The possibility of diagnosing the aneurysm from the plain roentgenograms on the basis of the anatomic relationships of the optic nerve and the ophthalmic artery within the optic foramen is discussed. The optic nerve lies in the upper inner aspect of the foramen, whereas the ophthalmic artery occupies the lower outer portion. In the reported case the erosion did involve the outer portion of the foramen, which corresponds in location to the ophthalmic artery. The inner aspect of the foramen, corresponding to the location of the optic nerve, was intact.

They conclude that when the above described erosion is seen, a presumptive diagnosis of ophthalmic artery aneurysm is justified.—*Dean Nichols, M.D.*

Wise, Burton L. Angiographic demonstration of the primitive trigeminal artery (carotid-basilar anastomosis). *Radiology*, May, 1957, *68*, 731–732. (Address: Department of Neurological Surgery, University of California Medical Center, San Francisco 22, Calif.)

The primitive trigeminal arteries appear in the 3 mm. human embryo, connecting the internal carotid arteries with the paired longitudinal arteries which eventually fuse to form the basilar artery. After the formation of the communicating arteries, at the 14 mm. stage, the trigeminal arteries regress as a rule.

The primitive trigeminal artery does not seem to have any pathologic significance when it does persist in the adult. The anomaly has been reported 10 times in about 3,200 arteriograms. In the case reported by the author the vessel was demonstrated angiographically. It was revealed as a large vascular channel joining the proximal subclinoid portion of the internal carotid artery with the mid portion of the basilar artery.—*Arno W. Sommer, M.D.*

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Schobinger, Robert, and Stoll, Henry C. The arteriographic picture of benign bone lesions containing giant cells. *J. Bone & Joint Surg.*, July, 1957, *39-A*, 953–960. (From The Roswell Park Memorial Institute, Buffalo, N.Y.)

The majority of benign bone tumors have normal vascular patterns. There is a small number, however, which tend to retain the radiopaque material but show no other changes.

In the past two years, 60 cases of bone or soft tissue tumors were studied with arteriography of which 3 are presented. Urokon-50 per cent was employed and 12 roentgenograms taken at one second intervals. Comparing the arteriograms with the histologic appearance, the authors consider that the "puddling" of urokon paralleled the concentration of giant cells in quantity and location rather than being related to the vascularity of the tumor. It is not stated whether or not other cases with giant cells showed similar findings.

Further investigation is warranted, but the histologic nature of a bone or soft tissue tumor cannot now be determined from the arteriographic pattern.—*Martha Mottram, M.D.*

General

Waldbott, G. L. Incipient chronic fluoride intoxication from drinking water. II. Distinction between allergic reactions and drug intolerance. *Int. Arch. Allergy*, 1956, *9*, 241–249.

With the addition of fluoride to drinking water, as well as the natural occurring fluorides in food and water, the author feels that one should be alert to symptoms occurring in individuals who have a lowered tolerance to drugs since there is a high incidence of these reactions. The present report differentiates allergic reactions to fluoride from chronic fluoride intoxication due to lack of tolerance to this drug, with case reports demonstrating different phases of the subject.

Three groups of symptoms can be noted: (1) Those associated with ingestion and elimination of fluorides; namely, manifestations on the mucous membrane of the mouth, stomach, bowels, and urinary tract. (2) Symptoms due to interference of fluorides with normal utilization of calcium and phosphorus by the body; namely, deposition of bone substance in joints and ligaments, especially in the lower spine, temporary hardening or sclerosing of the so-called hard structures of the body (bones, teeth,

nails, and hair), followed by softening in the bones and nails. (3) Interference of fluorides with cellular oxidation and with practically every known enzyme. Visual disturbances, partial paresis of the arms and legs, headaches, and extreme physical and mental sluggishness may thus be explained.

Roentgenologic examination of the gastrointestinal tract reveals no findings and bone changes are very difficult to evaluate. In the author's opinion the increased urinary calcium output appears to be a major diagnostic feature. Urinary excretion of fluoride does not normally reflect the patient's tolerance to the drug, and yields no information about the chances of intoxication. Many individuals may eliminate or store large amounts of fluoride without ill effect. A highly individualized tolerance to the drug seems to be the determining factor in the production of allergy and toxic symptoms. The reproduction of symptoms from intradermal skin tests and following ingestion of specific doses of fluorides (unknown to the patient) is an excellent diagnostic aid in differentiating between allergic reaction to fluoride and insipid fluoride intoxication. The appearance of allergic manifestation such as urticaria, dermatitis and allergic nasal disease indicates that a reaction is due to allergy. Intradermal skin tests cannot be fully relied upon, but are conclusive when positive. Immediate onset of symptoms suggests but is not conclusive evidence of an allergic reaction.—*K. K. Latteier, M.D.*

Silverman, Frederic N., and Cohen, Jerome. Dark adaptation with limited light and color vision. *Radiology*, May, 1957, *68*, 733–738. (Address: F. N. Silverman, Children's Hospital, Cincinnati 29, Ohio.)

The authors report the results of studies to determine the degree of dark adaptation obtained by various types of light-restricting devices. The most common form of dark-adaptation glasses in use at the present time is a shielded face-fitting goggle with a red plastic filter. This permits light of the longer wave lengths to pass, but effectively restricts the wave lengths below 600 millimicrons and decreases the total intensity of light of all wave lengths entering the eyes. During the period of dark adaptation or accommodation, the radiologist's activity is necessarily restricted. He cannot examine films and is handicapped by the lack of color vision. Any device or procedure which would decrease the inconvenience of dark adaptation would therefore serve a useful pupose.

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RADIATION THERAPY

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JENNINGS, W. A., and MCCREA, A. L. Dose distribution in conical rotation therapy with a 2-MEV generator. *Radiology*, May, 1957, *68*, 689–697. (Address: W. A. Jennings, Royal Northern Hospital, London N. 7, England.)

The concept of conical therapy is not new. It was used as early as 1906 by Kohl, who suggested a technique in which the roentgen ray tube revolved about a vertical axis, centered on the lesion to be treated. Later it was modified so that the patient was positioned on a cot, which rotated on a vertical axis under a fixed inclined roentgen ray beam. The method was developed for the 200–250 kv. range available at the time. Later the method was extended to supervoltage radiations of the Royal Cancer Hospital, London. In order to preserve the skin-sparing effect at this quality, they did not use a wax cone in the path of the radiation, and the beam was aimed deep to the lesion center. An alternative approach consists in using a wax cone on the patient surface, so as to reduce the rate of fall in dose level along the rotation axis, the beam being aimed directly at the lesion.

The authors report the results of studies to ascertain the relative merits of the two approaches in terms of dosage distribution, percentage depth dose, and ease of application. The technique utilizing a surface cone was found to offer significant advantages.—*Arno W. Sommer, M.D.*

JENNINGS, W. ALAN. Percentage depth dose in moving-field therapy. *Radiology*, May, 1957, *68*, 698–707. (Address: Royal Northern Hospital, London N. 7, England.)

Moving-field techniques in radiation therapy are being used more and more as the difficulties of immobilizing the patient and setting up the treatment are decreasing. The attainment of adequate percentage depth doses and their measurement has been the subject of much recent investigation.

The author discusses factors which influence this percentage and presents ten sets of curves relating to the percentage depth dose. These have been computed for homogeneous phantoms to demonstrate (1) the effects of varying certain physical factors for particular techniques, (2) comparisons between different techniques, and (3) the advantages of supervoltage over 250 kv. qualities in this respect.

Two principal techniques were selected for study, one "long-axis" and one "short-axis" rotation with the former represented by the rotating chair technique in which the patient rotates continuously (360°) in front of a static roentgen ray beam. The latter technique is represented by one form of conical therapy in which the patient rotates in a horizontal plane under a static inclined beam with the treatment being delivered from both sides of the patient. Two other techniques consisting of conical therapy with wedge filtration, and 180° arc (or pendulum) therapy in which the roentgen ray tube oscillates to and fro over the static patient are briefly compared.—*Donald N. Dysart, M.D.*

HINMAN, FRANK, JR., and SHELINE, GLENN E. Limitations of radioisotope therapy for prostatic carcinoma. *J. Urol.*, June, 1957, *77*, 871–874. (From: The Departments of Surgery-Urology and Radiology, University of California School of Medicine, San Francisco, Calif.)

The results obtained by radioactive gold and chromic phosphate directly injected into prostatic neoplasm would appear to be palliative only. It has been shown that the radiocolloids placed within the tumor do not become distributed evenly in all portions for curative purposes. This has been demonstrated by radioautographs and microscopic sections. Other studies have shown that the colloidal material does not completely pass through normal lymphatics and there is considerable doubt that it can pass through lymphatics involved by tumor tissue. In some instances, no demonstrable irradiation damage could be detected in the regional lymphatic tissue following administrations of these drugs.

The authors state that further work should be done to determine, 1) whether the immediate painful effect can be regularly avoided, 2) whether transurethral resection of the prostate is preferable, and 3) whether antiandrogen therapy, plus isotope injection is really more effective than antiandrogen therapy alone. Since the metastatic lesions are not affected by locally injected radioactive isotopes, there is also this question: Will these patients have easier deaths with fewer local complaints?—*George W. Chamberlin, M.D.*

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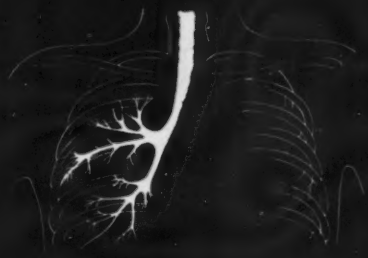

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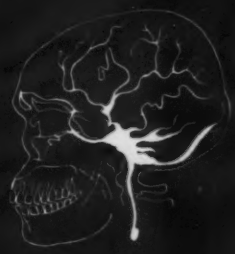

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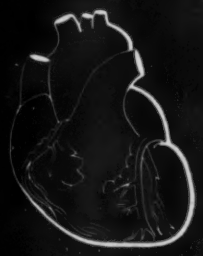

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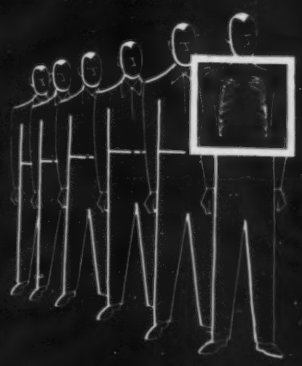

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1. Kaufman, S. A.: Am. J. Roentgenol. 78:725 (Oct.) 1957
2. Birnkrant, M.: Scientific Exhibit, A. M. A., Chicago, June, 1956

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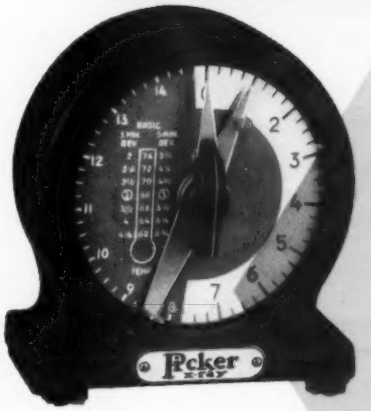

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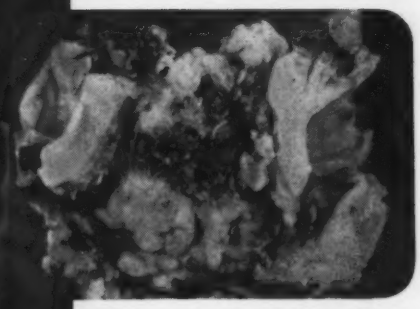
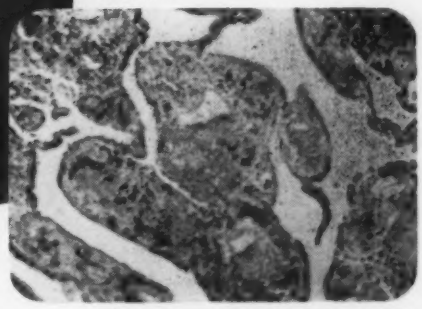


Photograph of a portion of the resected synovium with attached menisci.



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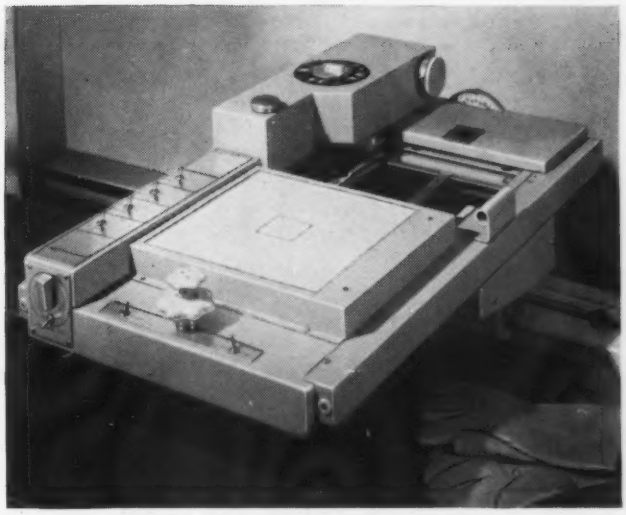

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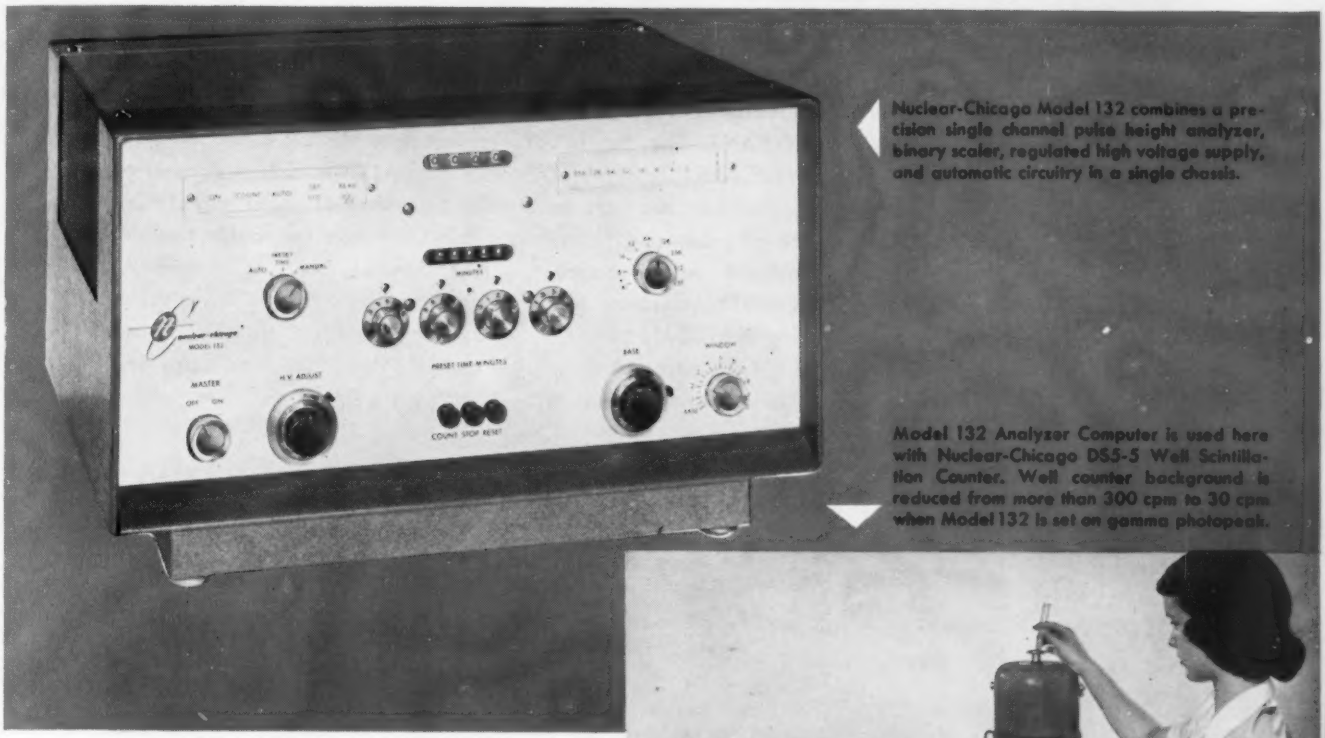
All-new Model 132 gamma-ray analyzer computer gives you automatic single-unit counting



Nuclear-Chicago Model 132 combines a precision single channel pulse height analyzer, binary scaler, regulated high voltage supply, and automatic circuitry in a single chassis.

Model 132 Analyzer Computer is used here with Nuclear-Chicago DS5-5 Well Scintillation Counter. Well counter background is reduced from more than 300 cpm to 30 cpm when Model 132 is set on gamma photopeak.

Here is your new automatic gamma-ray counting system in one compact, versatile unit. Nuclear-Chicago Model 132 Analyzer Computer combines a precision pulse-height analyzer, a reliable binary scaler, extremely stable high voltage supply and a push-button computing circuit for use with all gamma-sensitive scintillation detectors.

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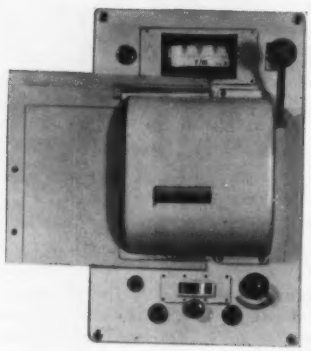

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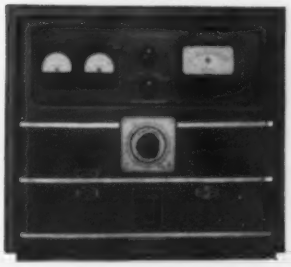

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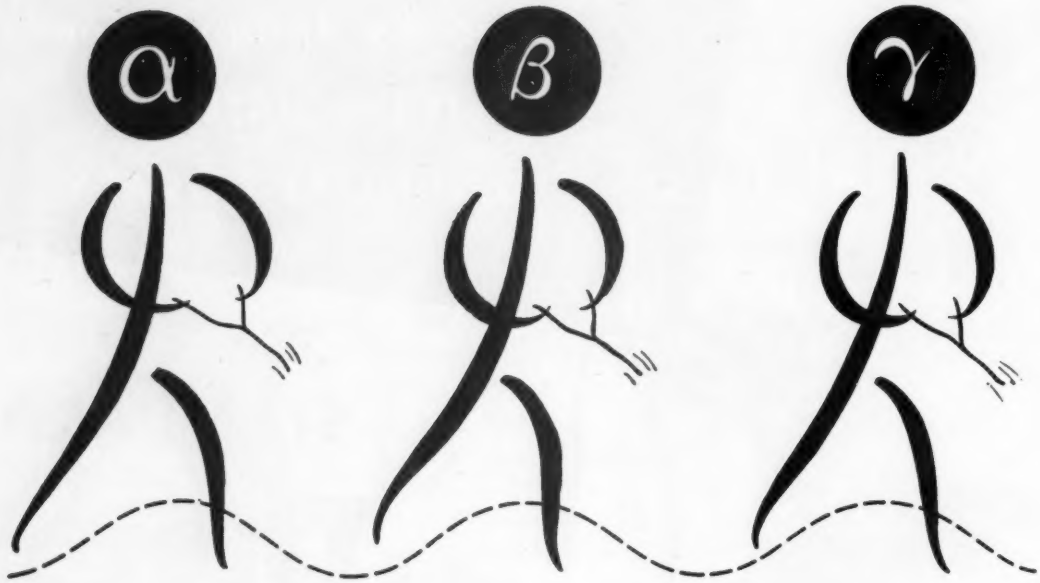

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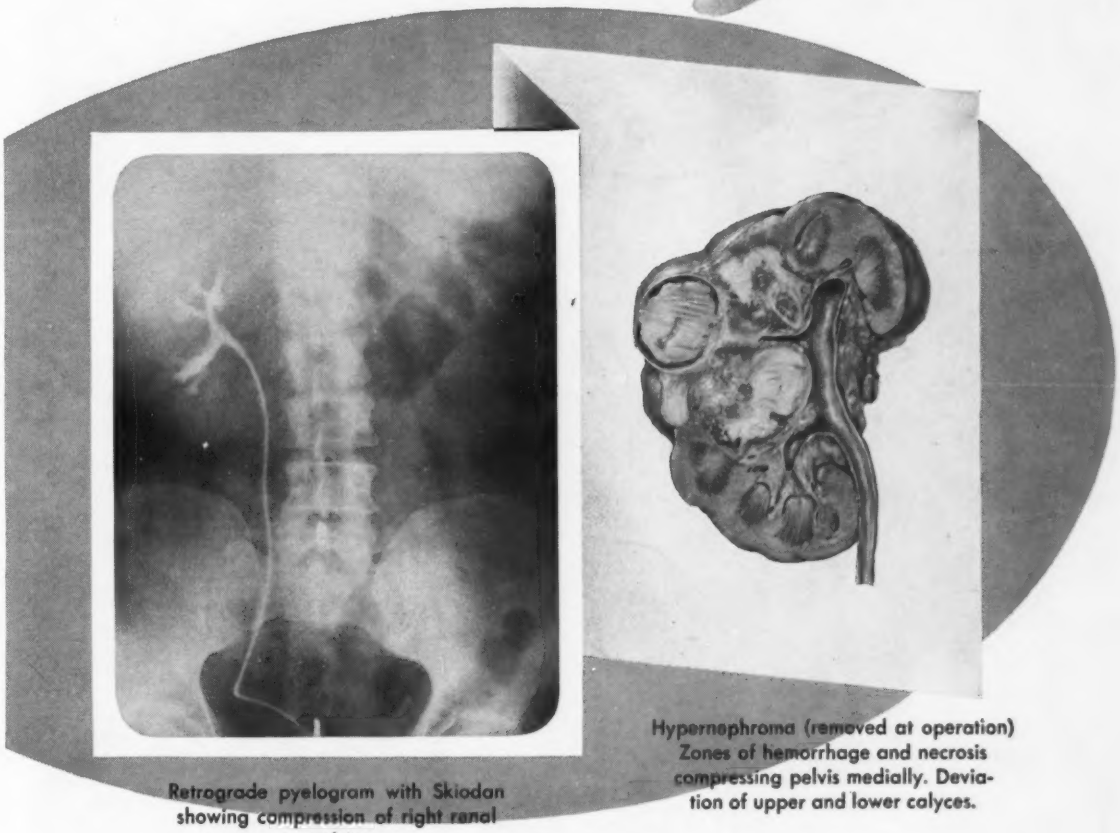

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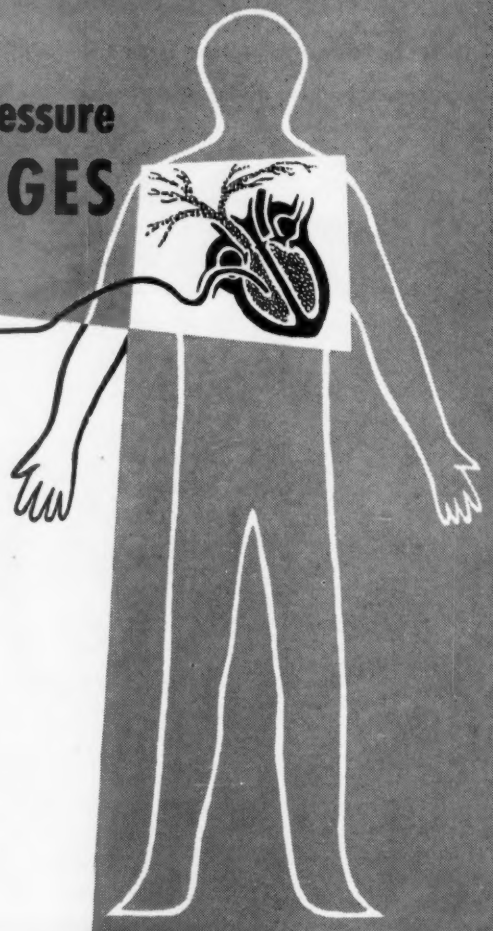

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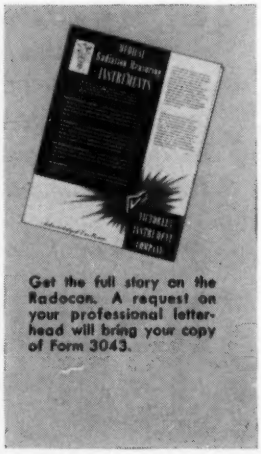

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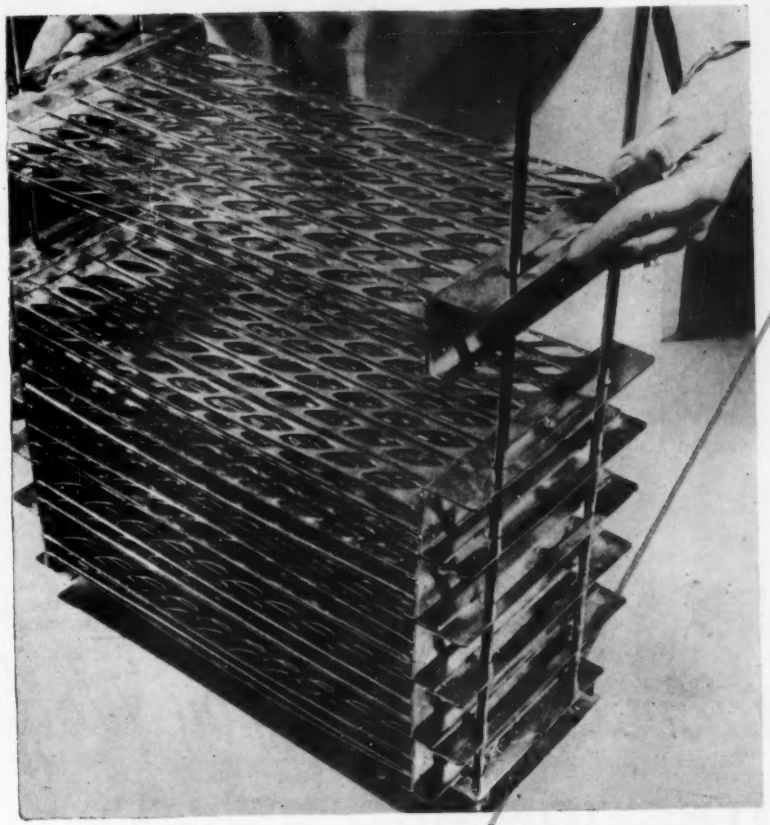

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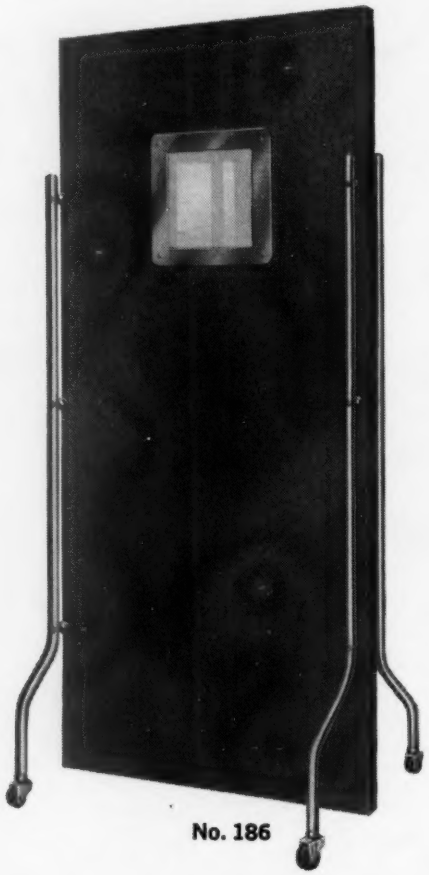

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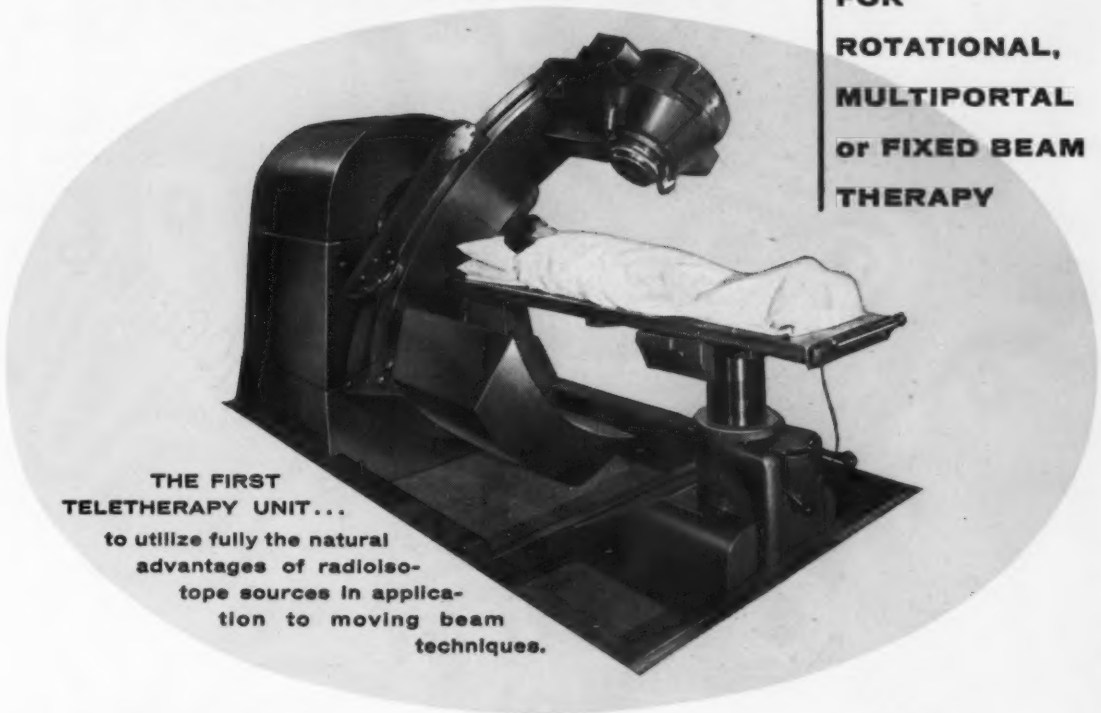

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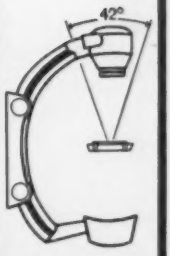

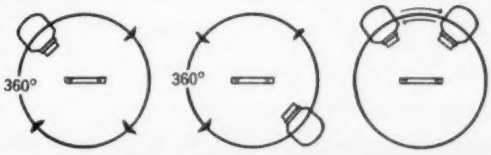

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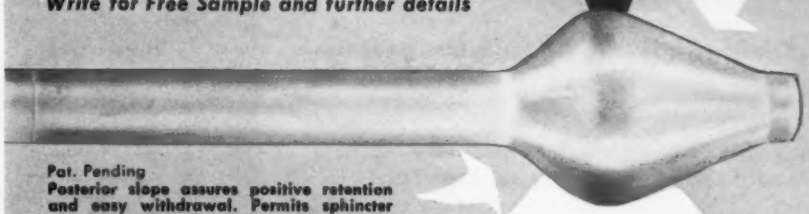

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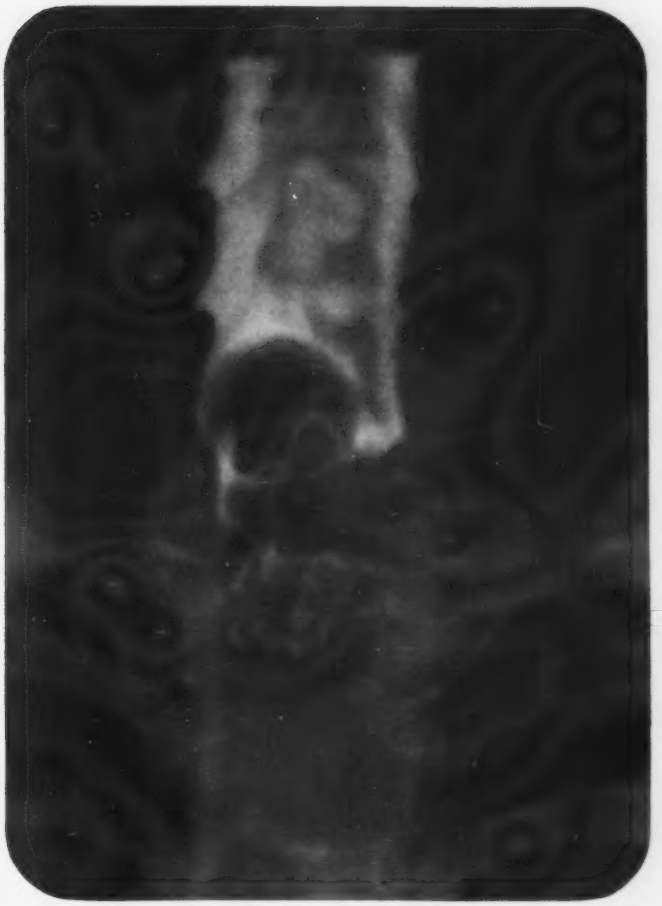

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BRITISH JOURNAL OF RADIOLOGY

SUPPLEMENT No. 7

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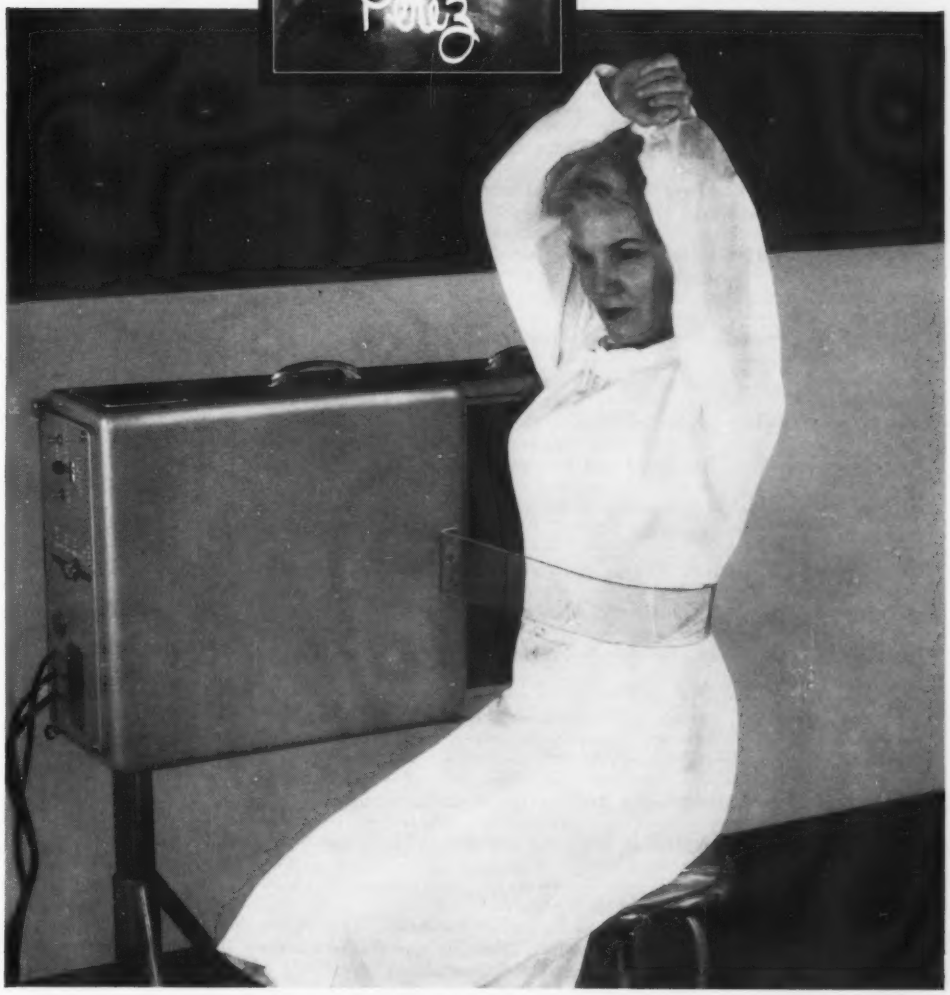

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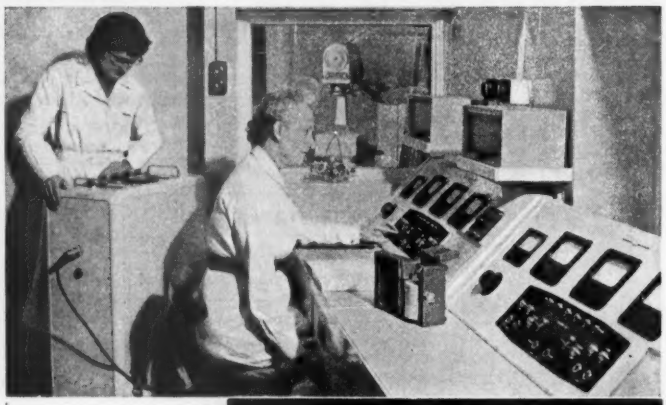

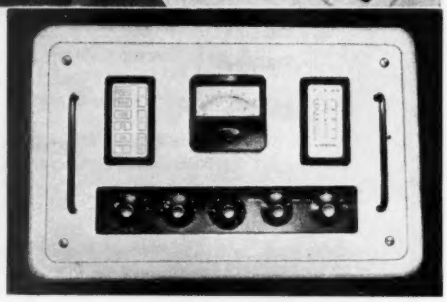

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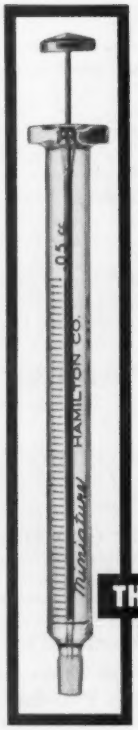

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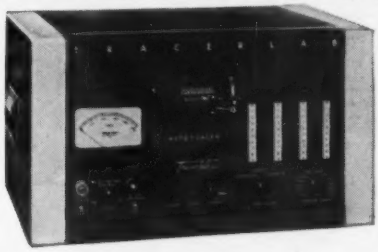

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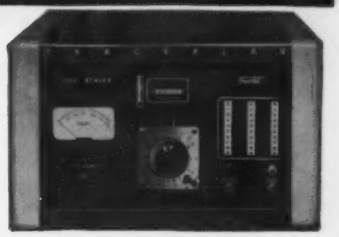

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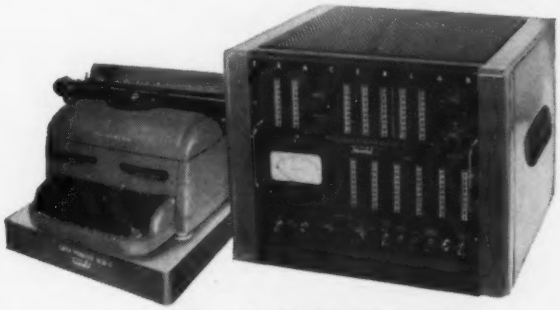

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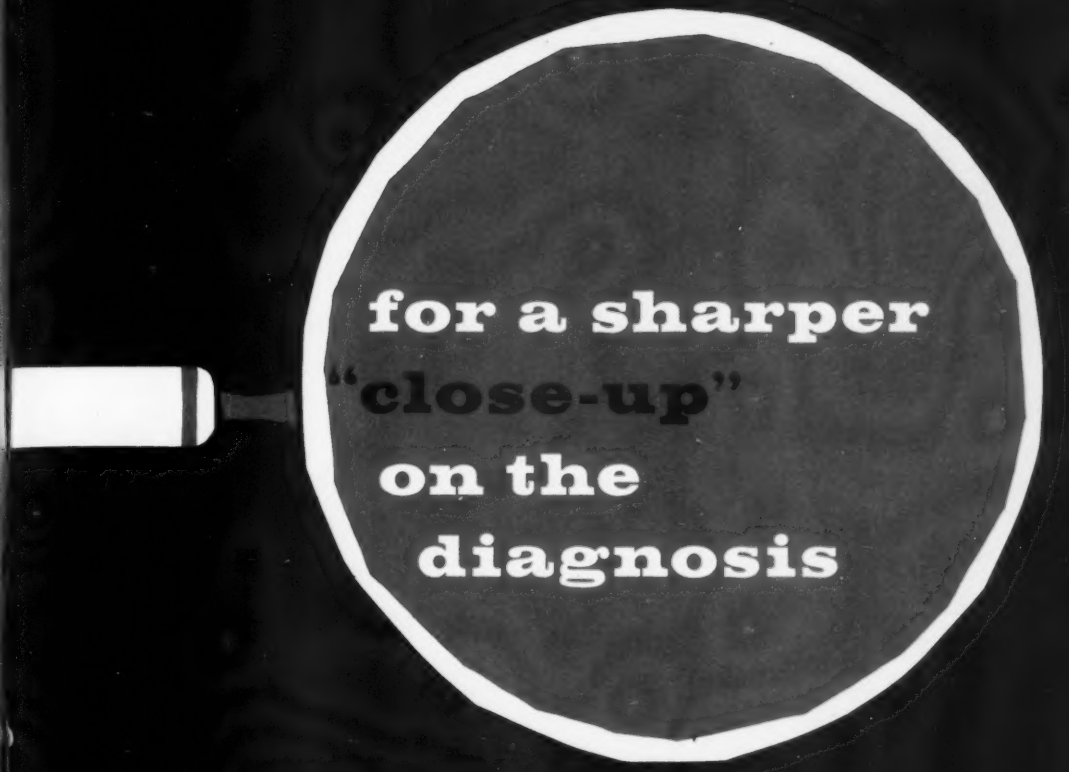

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[1] Shapiro, R.: Radiology *60*:687, 1953.

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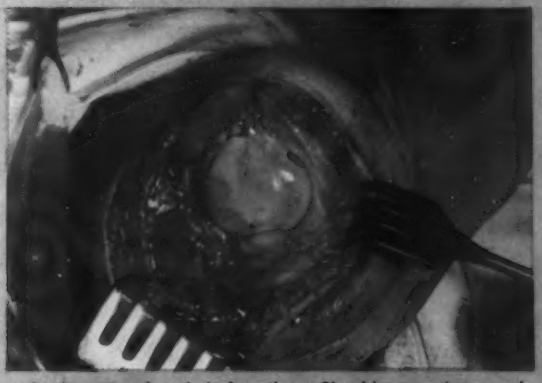
2. Skin draped. Saber incision outlined at acromion.



3. Acromion denuded of cartilage. Shoulder capsule opened.

4. Acromial process of the scapula osteotomized.
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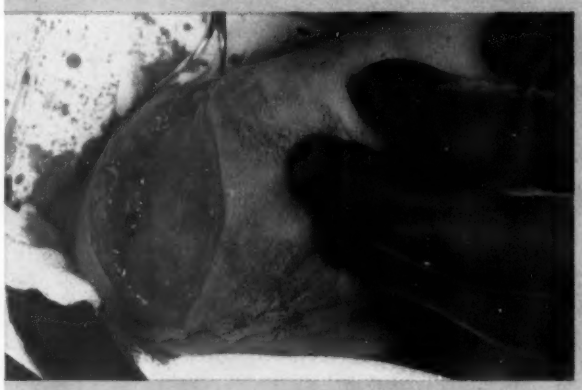
5. In succession: Flap is osteotomized in head of humerus; cartilage is denuded from head of humerus, which is joined to acromial process.

6. Acromial process now in head of humerus.



7. Cuff of shoulder capsule reefed to scapula.

8. Wound closed and prefitted cast applied.

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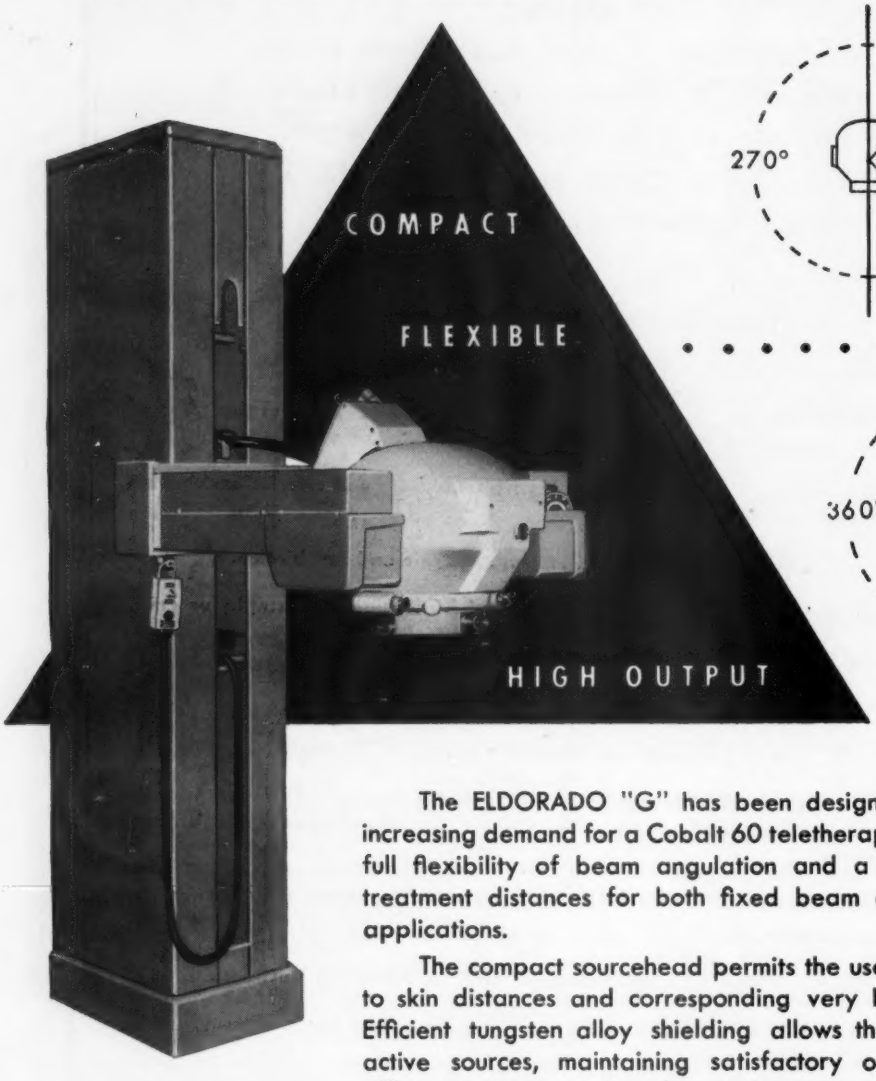

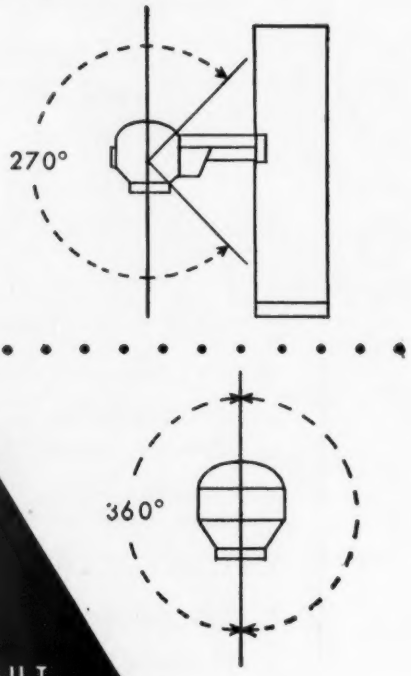

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